Paradise Regained

SOLUTIONS FOR RESTORING YOSEMITE'S HETCH HETCHY VALLEY

ENVIRONMENTAL DEFENSE

finding the ways that work

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Our mission
Environmental Defense is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

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Foreword

Douglas P. Wheeler
and Huey D. Johnson

More than a decade ago, the renowned Harvard biologist, E.O. Wilson, spoke of the need of repairing, where possible, the environmental damage which is an unfortunate legacy of heedless development in sensitive areas. In his seminal book, *The Diversity of Life,* Wilson urges that we now "go beyond mere salvage to begin the restoration of natural environments, in order to enlarge wild populations and stanch the hemorrhaging of biological wealth."

To a remarkable extent, 21st-century Americans have taken Wilson's updated definition of the public trust to heart, and are everywhere engaged in restoration projects small and large. Some are audacious indeed, striving to reweave and restore entire habitats on a scale as large as Florida's Everglades, the Chesapeake Bay, and San Francisco's Bay-Delta Estuary; others are as small as the watersheds of local, but nonetheless productive, creeks and tributaries. These projects result from the growing conviction that we have the capability, if not the obligation, to make amends for past mistakes, using newfound scientific knowledge and advanced technologies.

We think of Wilson's words as we read this report on the development of feasible alternatives to the water supply and hydroelectricity, which are currently provided by the O'Shaughnessy Dam on the Tuolumne River in the Hetch Hetchy Valley. Almost from the time of its construction early in the last century, visionaries have argued for the restoration of Hetch Hetchy to its splendid natural condition. Perhaps they can be excused for having given short shrift to the social and economic consequences of so bold a vision: millions of northern Californians have come to depend on the water and power of the Hetch Hetchy system. Whatever one's opinion of the merits of the original decision or of federal and state water policies as they evolved over the last century, however, no plan for the restoration of the Hetch Hetchy Valley, no matter how felicitous, can be considered without addressing this dependency on the current system.

Indeed, restoration advocates bear the burden of proving that alternatives can be made to work. In accepting this challenge, Environmental Defense, with the help of three distinguished consulting firms, has produced an extraordinarily thorough and thought-provoking assessment. As veterans of many an environmental controversy, we know that a lengthy dialog must precede any decision as momentous as the proposal to restore Hetch Hetchy and that the legitimate concerns of all stakeholders must be addressed. We welcome the publication of this report as an essential element of that dialog, coming at a time when the San Francisco Public Utilities Commission must make costly long-term decisions about upgrades to its Hetch Hetchy infrastructure. It is also time, as E.O. Wilson suggests, to begin "reweaving the wondrous diversity of life that still survives around us."

Douglas P. Wheeler and Huey D. Johnson both served as Secretary for Resources, State of California, in 1991–99 and 1978–82, respectively. Doug Wheeler presently chairs the National Park System Advisory Board and was formerly Executive Director of the Sierra Club and co-founder and President of American Farmland Trust. Huey Johnson was formerly the Western Regional Director of The Nature Conservancy and founder and President of the Trust for Public Land. He presently leads the Resource Renewal Institute.

Acknowledgments

Environmental Defense thanks the many individuals who have made financial contributions large and small to the completion of this report. We also thank all individuals who have made contributions to the report's final text.

We particularly acknowledge the significant contributions made by three independent technical consultants—Schlumberger Water Services; Eisenberg, Olivieri & Associates (EOA); and Somach, Simmons & Dunn. They report their detailed findings in Appendices A, B, and C, respectively. All interpretations of their findings in this report are our own.

We owe special thanks to the San Francisco Public Utilities Commission, the Bay Area Water Supply and Conservation Agency, the Turlock Irrigation District, and the Modesto Irrigation District, all of whom helped us prepare a more complete and accurate study. While the SFPUC, MID, and TID provided helpful comments, their assistance in no way endorses the study's findings and recommendations.

Many state- and federal-agency staff provided data, information and photographs for use in this report, for which we are very grateful. We also thank the Bancroft Library for providing access to the O'Shaughnessy Collection, which contained many of the photographs used in this report.

We very much appreciate the helpful comments received from Dr. Jay Lund and Sarah Null of U.C. Davis, on the TREWSSIM model developed for the study. In addition, we thank Dr. Richard Ferguson of the Center for Energy Efficiency and Renewable Technologies and Dr. James Bushnell of the U.C. Energy Institute for reviewing the study's hydropower-replacement analysis. And we thank Dr. George Tchobanoglous and Dr. Bob Cooper for their review of EOA's contributions on water quality. All statements of fact and opinion found in the text of this report, however, are ours alone and we bear full responsibility for them.

We are very thankful as well to Janice Caswell for her art direction, Bonnie Greenfield for her design and production efforts, and Steven J. Marcus for his editing of the manuscript. We also thank the many others—particularly Marcia Aronoff, Melinda Taylor, Pam Vivian, David Yardas, Johanna Thomas, Jennifer Witherspoon, Meredith Niess, Kate Larsen, Brandon Hunter, Elaine Capers, Terrel Hutton, Allison Cobb, Tim Connor, Joel Plagenz, and Peter Klebnikov—who were instrumental in the report's proofreading, editing, photo research, data collection, and other elements of production. We owe special thanks to Yolanda Cazessus for her exceptional commitment and patience throughout the report preparation. Finally, we thank those who helped more broadly on this project, including Fred Krupp, Tom Belford, Steve Cochran, Colin Rowan, Victoria Markell, Joy Carrigan, and Lisa Domitrovich.

About the authors

John Balbus is a physician and director of the health program at Environmental Defense. He has published on a range of topics including health consequences of global climate change, susceptibility to waterborne contaminants, microbial risk assessment and lead neurotoxicity. Balbus received his undergraduate degree in biochemistry from Harvard University, his M.D. from the University of Pennsylvania, and a master's in public health degree from Johns Hopkins University.

Tom Graff co-founded the California office of Environmental Defense in 1971. For over three decades, he has worked to protect and restore California rivers, wetlands, lakes and estuaries. Graff played a central role in the passage in the U.S. Congress of the Central Valley Project Improvement Act of 1992, in the signing of the San Francisco Bay-Delta Accord of 1994 and in the formation of the federal Bay-Delta Act of 1996. A past member of the Bay-Delta Advisory Council, the University of California's Agriculture and Natural Resources Advisory Commission, the National Research Council's Commission on Geosciences, Environment and Resources, and the Colorado River Board of California, Graff has also taught at the University of California's Boalt Law School and at Harvard Law School. He has an LL.M. from the London School of Economics and a J.D. from Harvard Law School.

Ann Hayden researches and analyzes water operations and policies throughout the state and works to protect aquatic resources and habitats in the West. Hayden coordinates with conservation partners and other interests to achieve sustainable water management solutions that restore ecological health and water quality throughout the San Francisco-Sacramento and San Joaquin Delta estuary ecosystem and its Central Valley and Sierra Nevada watershed. She is a committee member of the State Water Plan update and the California Urban Water Conservation Council. She has a master's degree in environmental science and management from the University of California, Santa Barbara.

Spreck Rosekrans specializes in hydrologic modeling and operations analysis to improve the timing and volume of flows to ecosystems in California and the West. His work has improved fishery and wetland habitat along the Colorado River in the Grand Canyon, on the Trinity River in northern California and in the Sacramento-San Joaquin Bay-Delta watershed. Rosekrans works closely with water agencies, Indian Tribes and conservationists throughout California, and was Convener of the multi-stakeholder California Water and Environmental Modeling Forum in 1999. He has a B.A. in Mathematics from the University of California, San Diego.

Nancy Ryan is an economist with expertise in energy markets and the health and ecological impacts of energy production. Since joining Environmental Defense in 2001, Ryan has led policy initiatives focusing on reducing greenhouse gas emissions from vehicles and power plants, curbing air pollution from diesel engines and restoring rivers affected by hydropower operations. Previously, Ryan worked as a consultant on a diverse array of energy-related projects. Since 1996, Ryan has also taught applied economics courses at U.C. Berkeley's Richard and Rhoda Goldman School of Public Policy. She has a Ph.D. in economics from the University of California, Berkeley.

Executive summary

Paradise lost

Imagine yourself in Hetch Hetchy on a sunny day in June, standing waist-deep in grass and flowers, while the great pines sway dreamily . . . These are the words of the great naturalist John Muir, who first visited Hetch Hetchy Valley in 1871. He praised it as a twin of nearby Yosemite, with comparable soaring cliffs and cascading waterfalls.

Today, we have to take Muir's word for it. Hetch Hetchy Valley lies submerged under 300 feet of water, a vast storage tank for the Bay Area. Congress preserved Hetch Hetchy Valley in 1890 as part of Yosemite National Park. But just two decades later, in a stunning political turnaround, Congress allowed Hetch Hetchy's Tuolumne River to be dammed, despite a nationwide outcry. It was the only dam of its scale ever erected inside a national park.

Hetch Hetchy Valley lies along the western slope of the Sierra Nevada mountains, 160 miles east of San Francisco and 3700 feet above sea level. The same glacial forces that sculpted Yosemite Valley created Hetch Hetchy. Glaciers gouged the Tuolumne River canyon, leaving towering granite domes and cliffs jeweled by waterfalls that once plunged hundreds of feet to the grassy valley floor.

Native Americans lived in Yosemite for millennia before the 1849 Gold Rush lured prospectors to the area. Soon, homesteaders began arriving. Alarmed by this onslaught, John Muir and other naturalists lobbied Congress to protect Yosemite. In 1864 President Lincoln signed a bill to preserve the area for "public use, resort, and recreation . . . inalienable for all time." In 1890, Yosemite National Park was born, encompassing Hetch Hetchy Valley.


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John Muir called Hetch Hetchy the "wonderfully exact counterpart" of Yosemite, likening its waterfalls and sheer granite walls to those in its more famous twin.

Yosemite Valley's Half Dome and John Muir, along with the California Condor, were chosen for the California quarter, due to be released in 2005.

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The ink on the park bill had hardly dried, before San Francisco proposed damming Hetch Hetchy Valley as a water source. Teddy Roosevelt's administration denied the City's requests as "not in keeping with the public interest." In 1906, a powerful earthquake and devastating fire struck San Francisco. The City's water supplies were ample but useless against the fire because quake-damaged pipes failed. Nevertheless, the pro-dam faction contended that too little water had allowed the fires to burn out of control.

The battle over the dam marked a turning point in America's attitude toward natural resources. Where once Americans supported unfettered progress, now many felt some things were too precious to lose. The public rallied behind Roosevelt's initiative to preserve the nation's unique features in a network of national parks, and the conservation movement, including John Muir's Sierra Club, came to life.

Today, there is a chance to return Hetch Hetchy to the American people. San Francisco has begun a $3.6 billion Capital Improvement Program to repair and modernize its water supply system. The overhaul presents a once-in-a-lifetime opportunity to modify the system to restore Hetch Hetchy Valley while continuing to provide safe, reliable water and power. Nearly a century of innovation has brought new technologies and options for meeting these needs.

About this report

In this report Environmental Defense provides a planning-level analysis for replacing the water and hydropower benefits that the Hetch Hetchy Reservoir and O'Shaughnessy Dam provide. We show how practical, proven water storage, conveyance and treatment alternatives can provide San Francisco a healthy, reliable and secure supply of water that is adequate for current and

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John Muir campaigned to save Hetch Hetchy, arguing that better sites were available to store San Francisco's water.

future needs. We also explain how hydropower lost as a result of restoring the valley can be replaced without contributing to air pollution or global warming. The alternatives analyzed do not comprise all possible options, but they do demonstrate that workable solutions for restoring Hetch Hetchy Valley exist.

We began this study with the premise that all solutions must be technologically feasible and affordable and must assure a dependable supply of safe drinking water. In addition to addressing the water and power needs of San Francisco and other Bay Area communities that rely on the Tuolumne River, solutions must also protect all affected California communities. Most obviously, any restoration plan must protect the Turlock and Modesto Irrigation Districts, whose uses of the Tuolumne River predate and are intertwined with those of the San Francisco Public Utilities Commission (SFPUC) and its customers. Of course, a restoration plan must also consider the Groveland area, both as a user of the Tuolumne River water and as a gateway community to the Hetch Hetchy region of Yosemite National Park.

Our analysis focuses mainly on alternative ways to move and store San Francisco's existing supply of Tuolumne River water. Environmental Defense developed the TREWSSIM (Tuolumne River Equivalent Water Supply Simulation) model to evaluate the SFPUC's system performance under a range of water supply alternatives, with and without Hetch Hetchy Reservoir. TREWSSIM incorporates features of both the SFPUC's planning model HHSM-LSM and the state-federal CALSIM model. The TREWSSIM analysis addresses not only water supply issues, but also water treatment and hydropower.

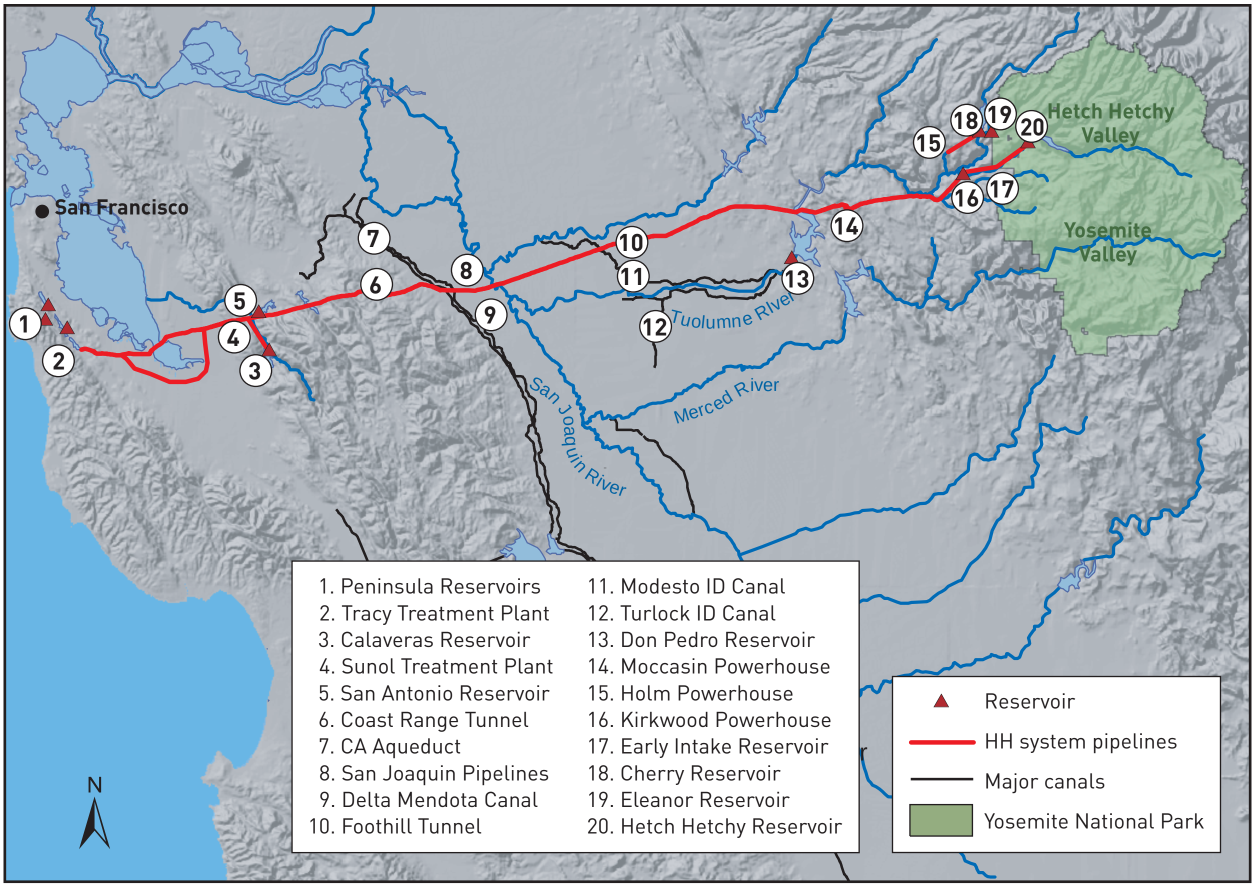
Three expert consultants assisted in our analysis: Schlumberger Water Services provided engineering analyses and modeling assistance; Eisenberg, Olivieri and Associates analyzed water quality issues; and Somach, Simmons & Dunn assessed the legal landscape. Academic experts provided peer review. The San Francisco Public Utilities Commission, the Bay Area Water Supply and Conservation Agency, and the Turlock and Modesto Irrigation Districts also provided information to help ensure an accurate report.

Ensuring adequate water supplies for today and tomorrow

Hetch Hetchy Reservoir is a key component of a water supply system that serves 2.4 million people in the San Francisco Bay Area (see Figure ES-1). Hetch Hetchy Reservoir holds 360,000 acre-feet of water, slightly less than 25% of the SFPUC's total storage capacity. The reservoir is also the principal diversion point for the Tuolumne River water that provides approximately 85% of the SFPUC's supply. The SFPUC sells about one third of this water within San Francisco and the rest to other Bay Area communities, which are represented by the Bay Area Water Supply and Conservation Agency (BAWSCA).

The 1913 Raker Act authorized San Francisco to construct a dam in Hetch Hetchy Valley and recognized its rights to a portion of the Tuolumne River's flow. The SFPUC shares the Tuolumne with the Turlock and Modesto Irrigation Districts (TID and MID). The Districts do not use Hetch Hetchy Reservoir, but do share storage with the SFPUC in Don Pedro, a reservoir downstream on the Tuolumne River that holds almost six times as much water as Hetch Hetchy Reservoir.

FIGURE ES-1
Overview of SFPUC water system and other Tuolumne River facilities



Hetch Hetchy Reservoir is part of an extensive system that includes several reservoirs, water treatment plants, hydropower facilities and a 160-mile series of pipelines and tunnels that carries Tuolumne River water from the Sierra Nevada to the Bay Area. Hetch Hetchy Reservoir holds less than 25% of the system's total storage capacity.

Under state law, TID and MID have water rights that are "senior" to San Francisco's and are entitled to most of the river's flow. San Francisco's rights are limited to occasions when the natural flow of the river is high and all of the Districts' needs are being met. In most years, these rights are more than sufficient for the SFPUC and its customers. In dry years, however, and especially in droughts, the SFPUC's share of Tuolumne River flow can't meet demand. Because the SFPUC depends on the Tuolumne River for 85% of its supplies, it must rely on storage in Hetch Hetchy, Don Pedro and its other reservoirs to ensure reliability for its customers.

Figure ES-2a provides an overview of the SFPUC's delivery objectives, storage capacity and water rights. Figure ES-2b provides the same information for the TID and MID, and delineates their obligation to release flows below Don Pedro Reservoir to support the lower Tuolumne River and its fisheries.

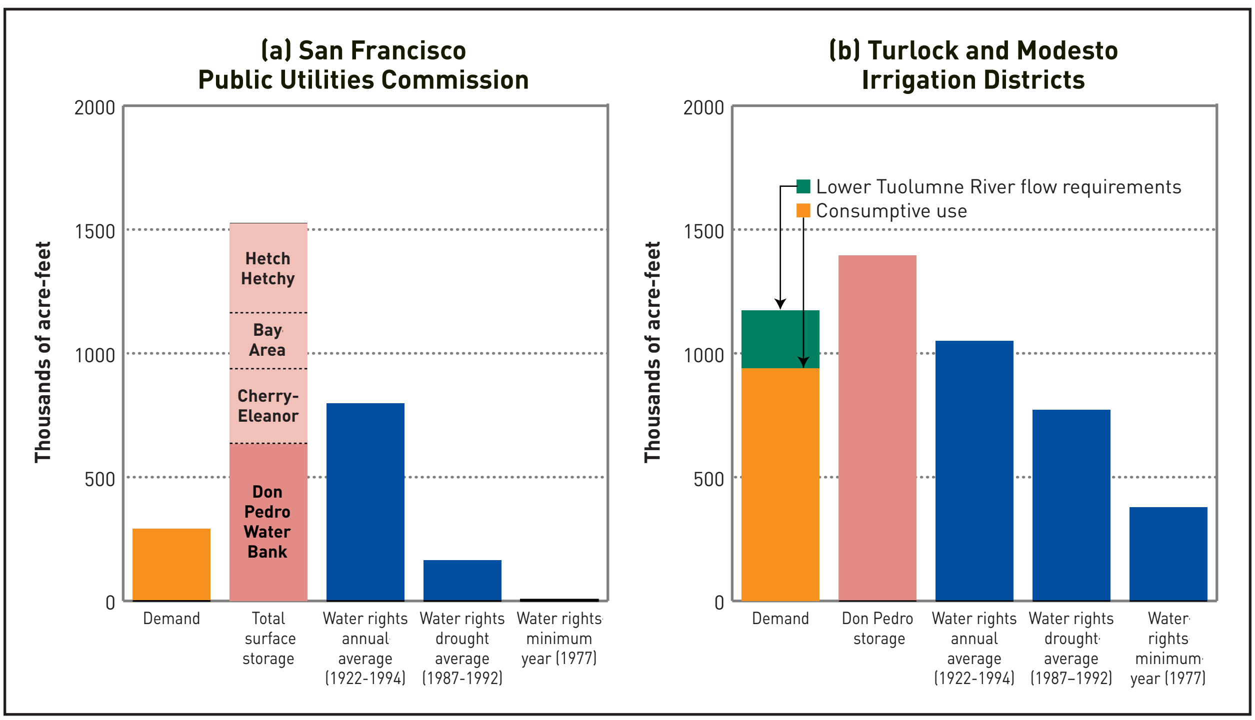
What we propose

Under our proposal to restore Hetch Hetchy Valley, San Francisco would continue to rely on Tuolumne River water for the vast majority of its needs using mainly the existing infrastructure. In winter and spring, the river's natural flow would be diverted as it is today. In summer and fall, system reservoirs outside Hetch Hetchy would provide enough water for all users, while leaving adequate "carryover" supplies as insurance.

The most obvious means of assuring reliable delivery of Tuolumne River water would be to tap the SFPUC's storage in Don Pedro Reservoir, which represents nearly double the volume of Hetch Hetchy. Presently, San Francisco uses its storage at Don Pedro Reservoir only as a "water bank," from which it repays the Turlock and Modesto Irrigation Districts, with whom it shares the reservoir's storage, when it diverts the Districts' supplies upstream in Hetch Hetchy Valley. Accessing SFPUC's water bank will require an intertie to be built connecting its San Joaquin pipelines to the Don Pedro Reservoir. This would allow the SFPUC to make full deliveries, with no loss of reliability from restoring Hetch Hetchy Valley, in most years. This report also includes a preliminary investigation of the feasibility of diverting San Francisco's share of Tuolumne River water further downstream, from the Sacramento-San Joaquin Delta.

San Francisco shared the cost of constructing Don Pedro Dam with the Turlock and Modesto Irrigation Districts and, as a result of a complex set of agreements with the Districts, has access to storage in Don Pedro that effectively provides it with the ability to divert Tuolumne River water even when flows are below the levels at which it has recognized water rights. Currently the City has no infrastructure to convey its Don Pedro supplies to the Bay Area, nor has it established the legal right to build

FIGURE ES-2
Delivery objectives, storage capacity, and water rights

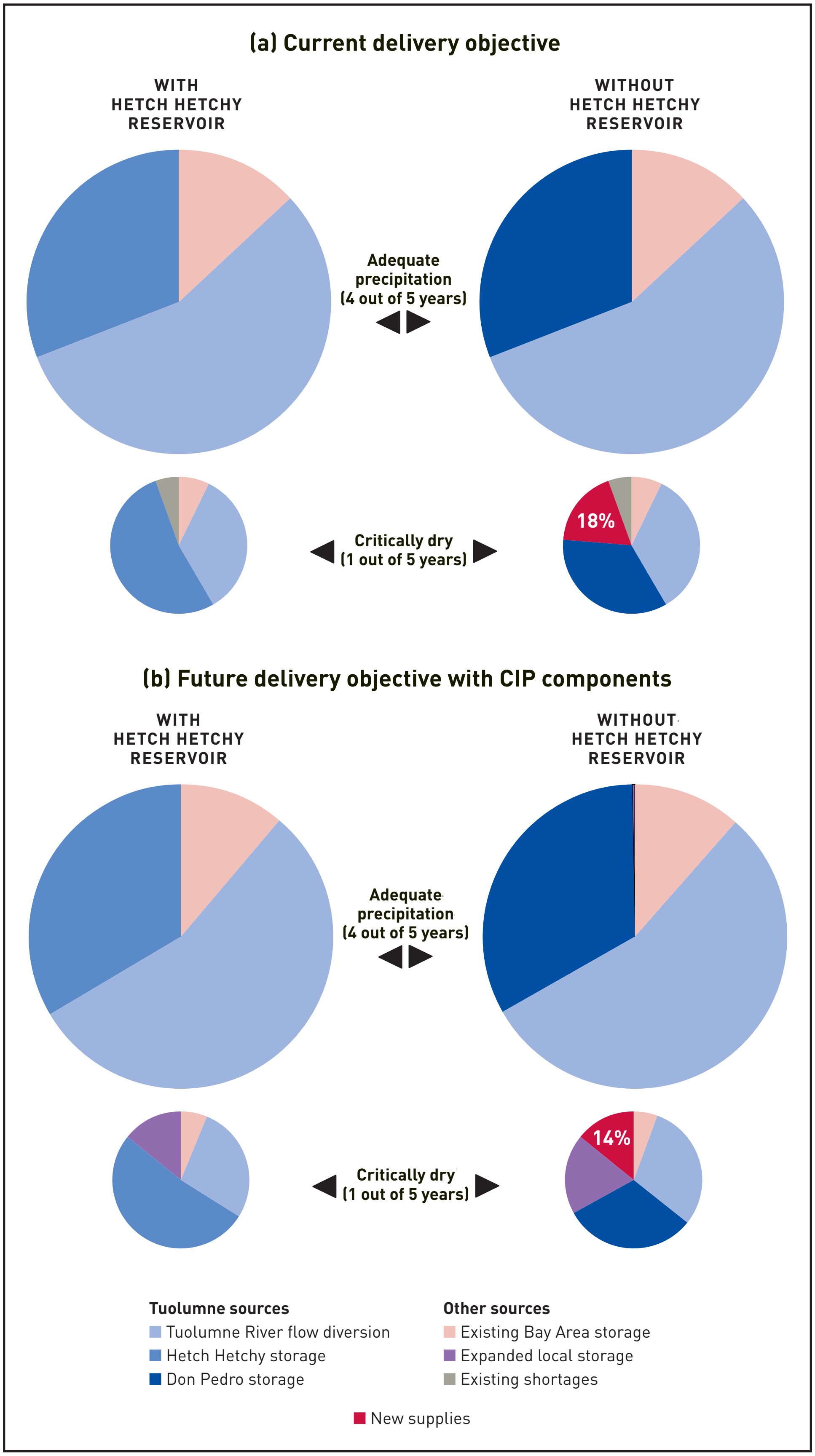


(a) In most years San Francisco's water rights are enough to meet its customers' needs. The SFPUC relies on storage in Hetch Hetchy, Don Pedro and other reservoirs to provide insurance against droughts, when its water rights are inadequate. (b) The Turlock and Modesto Irrigation Districts share the Tuolumne River with San Francisco, holding "senior" water rights that predate the City's. The Districts store water in Don Pedro for irrigation and domestic use and release flows below the reservoir to support the lower Tuolumne River and its fisheries.
Source: SFPUC

FIGURE ES-3

Sources of SFPUC water supply with and without Hetch Hetchy Reservoir

(a) Without Hetch Hetchy Reservoir, the SFPUC could meet customer demand in most years using Tuolumne River water and runoff captured in existing Bay Area reservoirs. In the driest 20% of years, a small amount of additional water would be needed. (b) The SFPUC can satisfy projected future demands without Hetch Hetchy Reservoir in all but the driest years if key elements of the CIP are built. In most years, local supplies and Tuolumne River water diverted directly from the river or stored in Don Pedro Reservoir would be adequate. During critically dry years, the SFPUC would also draw on Tuolumne River water stored off-stream in an expanded Calaveras Reservoir and a small reserve of additional supplies.



any such infrastructure. To construct an intertie between Don Pedro reservoir and the SFPUC's conveyance system would require the cooperation of the Turlock and Modesto Irrigation Districts.

Under either of these alternatives, San Francisco could still take much of its water supply directly from high up on the Tuolumne River. These "run-of-river" diversions would take place just a few miles downstream from Hetch Hetchy Valley at the Early Intake Diversion Dam, where the SFPUC diverted all water to the Bay Area until 1967. The rest of the supply, as is now the case, would be provided by diversions of stored water that would be sent to the Bay Area during periods of low flows, typically the late summer and fall months. The main difference would be that water awaiting shipment to customers would be held at Don Pedro Reservoir instead of in Hetch Hetchy Valley. Under a Delta Diversion alternative the stored water would move through the natural river channel instead of San Francisco's pipelines.

As illustrated in Figure ES-3a, TREWSSIM modeling shows that without Hetch Hetchy Reservoir the SFPUC could still provide full deliveries to its customers in most years using Tuolumne River water and runoff captured in its existing Bay Area reservoirs. In the driest 20% of years, additional supply would be necessary to fully meet demands without reducing storage to an unacceptable level or imposing "shortages," as the SFPUC has done during recent droughts.

The modeling also shows that if key elements of the Capital Improvement Program (CIP) are built, the SFPUC can also fully satisfy projected future demands without Hetch Hetchy Reservoir in all but the driest years. Figure ES-3b shows that local supplies and Tuolumne River water diverted directly from the river or stored in Don Pedro Reservoir would be adequate to serve the SFPUC's customers in most years. In critically dry years the SFPUC would also draw on Tuolumne River water stored off-stream in an expanded Calaveras Reservoir, but without storage at Hetch Hetchy would need to tap a small reserve of additional supplies.

An expanded Calaveras Reservoir and a fourth San Joaquin pipeline are elements in San Francisco's CIP that would help provide increased water supplies to meet projected increases in demand. Environmental Defense does not assume that these elements will be expanded or take any position at this time on the expansion. This report simply uses these elements of the CIP to project one possible future for the SFPUC against which to compare alternatives for restoring Hetch Hetchy Valley.

Several cost-effective and dependable sources are available to augment existing water supplies during critically dry years. Although they would be more costly on a per-unit basis than the bulk of San Francisco's water, the incremental supplies would only be required in one in five years, and even within those years would constitute only 14–18% of total supply. So their overall contribution to the cost of water in the Bay Area over the long term would be low. This report focuses on three supplemental water sources, all of which are being used by water agencies throughout California and have been investigated by the San Francisco Public Utilities Commission:

- **Increased local storage.** San Francisco is investigating expanding Calaveras Reservoir in its Capital Improvement Program and has identified other potential sites for local reservoir expansion. In recent years, the Metropolitan Water District and Contra Costa Water District have built Diamond Valley and Los Vaqueros reservoirs, respectively, near their own service areas to enhance water supply reliability.

- **Groundwater exchange programs with agricultural agencies.** San Francisco has identified groundwater exchange as a potential source of supply but has not yet successfully completed any agreements. Santa Clara Valley Water District, Alameda County Water District, Zone 7 and Metropolitan Water District have contracted with Semitropic or Arvin-Edison Water Storage Districts to increase reliability in dry years.
- **Dry-year purchases from irrigation districts.** San Francisco identifies water transfers in its Water Supply Master Plan as a source of supply but has not yet successfully completed any agreements. Recent long-term transfer agreements throughout California have helped to shore up supplies for a variety of urban agencies. The most widely publicized is the historic agreement in 2003 between the Imperial Irrigation District and the San Diego County Water Authority.

Providing safe water for all

Safe, clean drinking water is essential to life. Any plan to restore Hetch Hetchy Valley must assure Bay Area residents who drink Tuolumne River water that the quality of their water will not be diminished if it is stored and diverted further downstream. Based on a review of raw water quality data from potential replacement sources, our consultants Eisenberg, Olivieri and Associates determined that "there does not appear to be any technical reason that the SFPUC Hetch Hetchy water supply system could not be operated without the Hetch Hetchy Reservoir" and made a series of recommendations for further water quality analyses that should be pursued concurrently with the investigation of water supply alternatives.

The SFPUC has been granted a rare exemption and is not presently required to filter its Tuolumne supplies. Flows that are diverted downstream of Yosemite National Park are likely to have higher concentrations of some constituents, necessitating additional treatment. Based upon available data, EOA found that with the addition of existing water treatment technologies, the water quality predicted to result from the Don Pedro or Sacramento-San Joaquin Delta systems should be comparable or superior to the quality of water from the current Hetch Hetchy system. In particular, filtration should reduce the presence of giardia and cryptosporidium to levels lower than those present in the current system. The addition of a water filtration system also provides an extra layer of protection and, along with other precautions in the watershed, would protect customers from contamination resulting from increased recreational use of the restored valley.

While public safety is paramount, other water quality characteristics such as taste, odor and appearance also matter to consumers. Adding filtration to the treatment process may reduce the amount of chemicals added in the disinfection stage. Augmenting filtration with additional treatment steps, especially for Delta supplies, will not only ensure the effectiveness of filtration but could also yield finished water that closely matches other aspects of existing water quality.

Currently San Francisco uses its Tracy and Sunol water treatment plants to filter and disinfect supplies stored in local reservoirs. As part of the CIP, San Francisco is already planning an expansion of its Sunol plant. All of the restoration alternatives considered in this study envision that San Francisco's entire water supply would be conventionally treated, including filtration.

Our analysis focused on water treatment technologies in use today in the United States. However, significant advances are being made in this field, and it is possible that new water filtration methods will soon cost-effectively provide even cleaner water than is projected using existing technology. It is also possible that even if San Francisco continues to store its water in Hetch Hetchy Valley, the Environmental Protection Agency may eventually require the City to filter its entire supply. Such a development would lower the total cost of restoring the valley by reducing incremental treatment costs for water stored and diverted lower in the Tuolumne River watershed.

Developing clean energy alternatives for Hetch Hetchy power

When Congress authorized San Francisco to dam Hetch Hetchy Valley, hydropower was the primary energy source for California's rapidly growing electricity system. As part of its grant to San Francisco, Congress directed the city to develop hydroelectric facilities "for the use of its people." Energy not used by the City was to be sold to TID and MID at cost. Since it first began generating electricity in 1918, San Francisco has steadily expanded its hydroelectric facilities in the Tuolumne watershed. Today it operates three powerhouses that generate electricity from the Tuolumne River and its tributaries.

Hetch Hetchy hydropower accounts for a tiny share of California's electricity supply, just 0.6% of total statewide generation in 2002, but it is an important and

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Without storage at Hetch Hetchy, the SFPUC would still derive most of its water supply from the Tuolumne River. Constructing a new intertie at or below Don Pedro Reservoir (shown above), would allow the City to have access to its supplies in the reservoir. To protect against contamination, the SFPUC would need to filter all of its water, as virtually all U.S. communities already do. The available data indicate that conventional treatment methods would yield water comparable or superior to the current quality of water from the current SFPUC water system.

inexpensive energy source for those who use it. In recent years, the City has used about one third of the Hetch Hetchy hydropower to serve public facilities such as the airport, San Francisco General Hospital and city offices. Most of the rest has been sold to TID and MID.

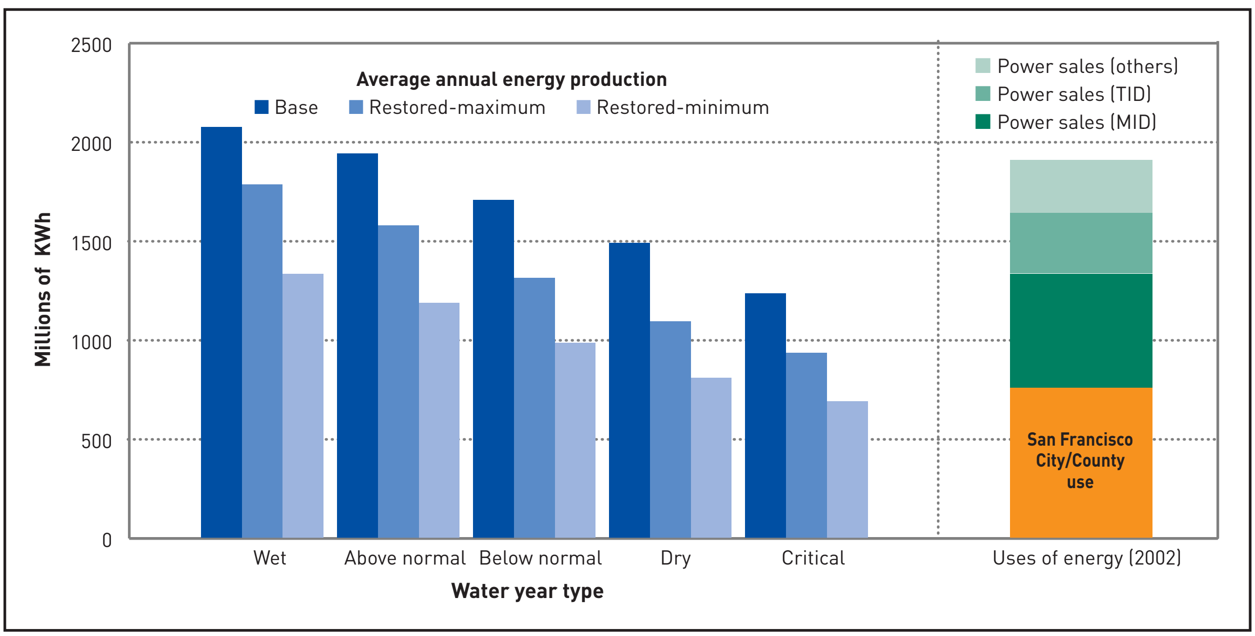
Restoring Hetch Hetchy Valley would reduce generation from two of the SFPUC's three Tuolumne River powerhouses. On an annual basis, the forgone energy could average up to 690 million kWh per year, about 40% of average annual generation. With modifications to the SFPUC's facilities, the average annual loss could be as low as 339 million kWh per year, just 20% of average annual generation. The SFPUC would lose relatively little valuable on-peak energy: most of the lost hydroelectric output would be base-load energy, which is relatively inexpensive to replace. Hydroelectric production at TID and MID's Don Pedro powerhouse could also decrease slightly (1.4%) or increase by as much as 10%, depending on how much water San Francisco withdraws from the Tuolumne River and whether the diversions take place above or below Don Pedro Dam.

If the valley is restored, the SFPUC's Tuolumne River hydroelectric plants would still provide enough energy to meet current municipal needs on an annual basis in all but the driest years (see Figure ES-4). In the latter half of the year, San Francisco would need to increase the amount of energy that it already purchases to augment hydroelectric output in order to meet its own needs. In dry years, the City might need to buy additional power at other times as well. Less surplus energy would be available to sell to TID, MID and others.

Several options are available to replace—or eliminate the need for—

FIGURE ES-4

Projected annual generation vs. 2002 uses of Hetch Hetchy hydropower



Hetch Hetchy hydropower accounts for a tiny share of California's electricity supply, but is a valuable energy source for San Francisco and the Turlock and Modesto Irrigation Districts. If the valley is restored, the SFPUC's powerhouses would still provide enough energy to supply the City's current needs in all but the driest years. The City would have to buy additional power at times, and less energy would be available to sell to the Districts and others. Renewable energy and investments in energy efficiency can cost-effectively fill the gap without increasing air pollution.

Source: US DOE Form EIA-861 and EIA-412

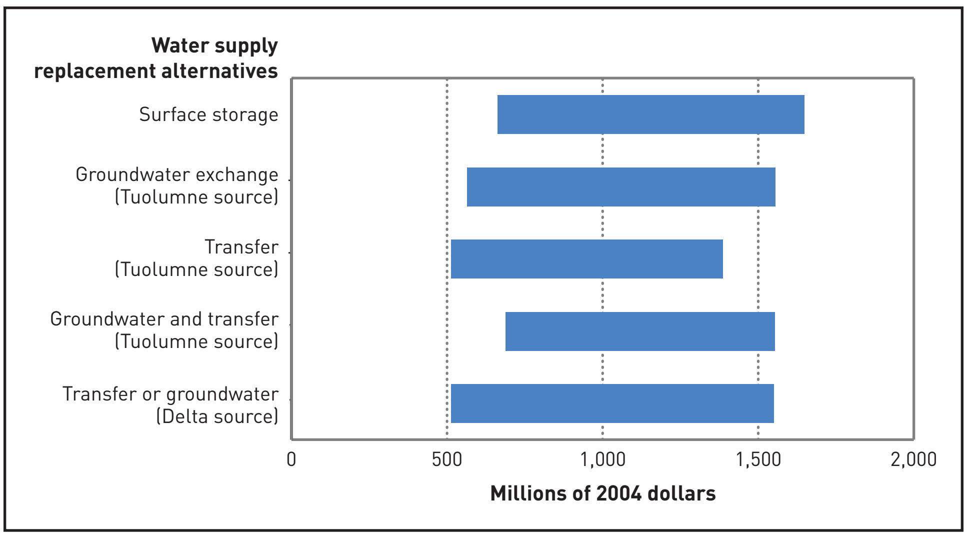
the lost energy. Demand-side measures, such as increased investments in energy efficiency and expansion of dynamic pricing programs, offer cost-effective means of displacing both the energy and capacity needs currently met by the SFPUC's hydropower facilities. New supplies could be obtained by purchasing power from or constructing new generating facilities. Renewable energy, especially solar and wind power, are the greenest new supply-side resources. New highly efficient gas-fired plants are the best available fossil-fueled alternative. In most parts of California, new gas-fired plants must install state-of-the-art pollution controls and offset all of their emissions of smog-forming chemicals and other criteria pollutants by finding ways to cut an equivalent amount of pollution from other sources. While not currently required by law, inexpensive approaches are available to offset greenhouse gas emissions as well.

The amount of hydropower that would be lost as a result of restoring the valley is dwarfed by the potential to save energy by improving efficiency. The power loss also appears negligible when one considers the potential to develop new sources of renewable energy, and the recent additions to California's fleet of power plants. More than a dozen new gas-fired power plants with a typical capacity of 500 MW have entered service in California since 2001, and less than 20% of the annual output of just one of them could replace all of the foregone energy.

Costs of replacing water and power

The cost of replacing the water and power services provided by O'Shaughnessy Dam ranges from $500 million to $1.65 billion. Figure ES-5 shows the range of estimated water and power replacement costs developed for each

FIGURE ES-5
Estimated range of water and power replacement costs



Our study focuses on the most challenging and expensive components of restoration—the costs of replacing the water and power services Hetch Hetchy Reservoir provides. Cost estimates vary depending on where replacement water supplies are diverted and stored. Costs also depend on key uncertainties, including the future level of demand, whether the SFPUC can continue to avoid filtering its entire water supply, the capital costs of restoration components, and how much restoration reduces hydropower generation. Devising an equitable approach to sharing these costs will be an essential element in developing a plan to finance the valley's restoration.

restoration alternative under a set of scenarios that account for critical uncertainties. Estimates of the annual and capital costs of water and power replacement alternatives follow usual conventions regarding discounting, in which future costs are included in the overall estimate at lower costs depending on how far in the future they will occur. A discount rate of 5% was used to convert cash flows to present values.

Each alternative considered in this study includes two key components—an expanded water treatment plant and construction of an intertie connecting the San Joaquin Pipeline with the lower Tuolumne River. The alternatives differ in the components they include for replacing existing water supply in dry years, since multiple workable solutions are available.

Many factors will influence the cost of implementing the water supply alternatives considered in this report, so it is difficult to predict which alternative will be the most cost-effective or how much its various elements will cost. For the purposes of this initial analysis, we identified some critical uncertainties that are most likely to have the largest impact on total costs. The estimated cost of each alternative was then computed under a variety of scenarios that take these key uncertainties into account:

- Whether the loss in hydroelectric power from the SFPUC's Tuolumne River powerhouses is at the high or low end of the range of estimated values;
- Whether the capital costs for new infrastructure are in the high or low range of estimated values;
- Whether the SFPUC will continue to use only chloramine to treat water diverted from the Tuolumne or begin to filter all of its supplies;
- Whether the SFPUC's delivery objective will increase as currently forecast from 260 to 303 million gallons per day.

While this study does not fully account for all costs, it does encompass the most challenging and costly components of restoration. We did not attempt to estimate the cost of removing O'Shaughnessy Dam, restoring Hetch Hetchy Valley or building facilities to accommodate the visitors from across the United States and around the world who would flock to see the valley and its unprecedented restoration.

We also did not try to place a monetary value on the many benefits of a restored valley. These would accrue to generations of future visitors who would come to Hetch Hetchy to hike, climb, picnic and revel in the scenery. Tuolumne county businesses along Highway 120 would profit from increased visitation. Also sharing the benefits would be people who never set foot in the valley but take pleasure simply in knowing that it has been restored. Indeed, in government sponsored cost-benefit analyses of recent proposals to restore rare landscape features such as Olympic National Park's Elwah River and California's Mono Lake, estimates of "existence value" have significantly exceeded the projected value to direct users.

Financing restoration

Our analysis focuses on estimating costs to society at large and does not address who should pay these costs. Clearly, determining who should pay these costs will be a major factor in developing a plan to finance the valley's restoration. The benefits of recovering a vital part of one of America's most revered national parks will be shared by millions of people nationwide and around the globe. The valuable water and power

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The Tuolumne River once meandered through wildflower-dotted meadows and groves of oaks, pines, and firs. A 1988 study by the National Park Service found that if the valley is drained Hetch Hetchy's plant and animal life would come back with some human assistance. This hand-tinted photograph suggests how a restored Hetch Hetchy Valley might appear.

services now provided by Hetch Hetchy Reservoir are shared by a much smaller number of Bay Area and Central Valley residents, and they stand to lose the most from restoration if they are not compensated for those losses.

As restoration alternatives are further explored and refined in the public process, a variety of funding sources should be examined to find an equitable way to pay for restoration. Sources could include federal and state governments, current users of Tuolumne River water and hydropower, user fees from park visitors and philanthropic donations.

Legal and institutional challenges and opportunities

Substantial legal and institutional hurdles must be overcome for restoration to be successful. On the other hand, a variety of authorities, including the Raker Act itself, the public-trust doctrine, and the California constitution's injunctions against the unreasonable use, diversion or waste of water, seem to require an ongoing consideration of alternatives that might lead to the valley's restoration. With public support, the opportunity to restore Hetch Hetchy Valley can be pursued in a variety of ways, including through the Corps of Engineers' review of San Francisco's Capital Improvement Program.

Legal challenges that must be overcome include the following:

- Congress must amend and modernize the Raker Act and authorize an altered set of purposes for using national park land.
- The State of California likely will need to affirm San Francisco's water use, diversion and storage rights in a new configuration and otherwise assure San Francisco, Turlock and Modesto Irrigation Districts, BAWSCA, and others that a fair resolution of the myriad issues raised by such major changes in San Francisco's water delivery and power generation system will be legally required prior to restoration.
- The affected entities—San Francisco, its customers, the Districts and others that have long shared the Tuolumne River's bounty—will need to negotiate new arrangements that respond to the legitimate water and power demands of all.
- Those who will benefit from the valley's restoration will need to share the cost of making it possible. The state legislature (or the state's voting public) and the U.S. Congress will be asked not only to promulgate the changes in law and to provide the necessary assurances that should accompany restoration, but also to share significantly in the funding of the arrangements required to provide those assurances.

WADSWORTH ATHENEUM

Albert Bierstadt's grand paintings of western landscapes, including this 1870s view of Hetch Hetchy Valley, allowed a generation of Americans to envision the region's natural wonders at a time when travel was arduous and prohibitively expensive. Today millions of visitors flock to Yosemite National Park each year and many would stop to see the restored valley.

Paradise regained? Conclusions

The idea of restoring Hetch Hetchy Valley is not new. In 1987, President Reagan's Interior Secretary, Donald Hodel, proposed dismantling O'Shaughnessy Dam. The following year the National Park Service produced a report investigating a range of alternatives for restoring the valley. The report concludes that a restored valley would eventually rebound. Within five years, mammals, amphibians and reptiles endemic to the area would return to the valley. After 10 years, meadows, willow thickets and conifer groves would begin to resume their original pattern. After 50 years, the valley would begin to appear as it once did. Over the next century, trees would mature, the bath-tub ring on the valley's walls would gradually fade away and Hetch Hetchy would recover its natural glory.

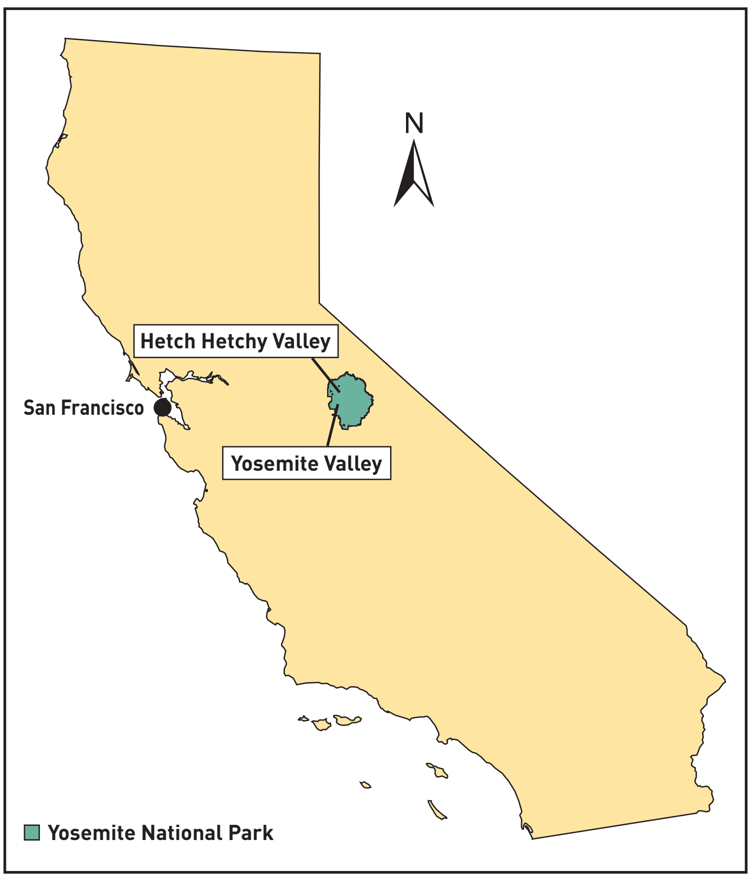
Nonetheless, returning Hetch Hetchy Valley to the American people will require a broad public effort. This study serves as a starting point. We call on local, state and federal officials to develop our findings and involve the public in a plan to restore the valley. With support from a dedicated public, imagination and a willingness on the part of officials to work together, perhaps an American paradise can be regained.

CHAPTER 1
Introduction

Imagine an earthly paradise where waterfalls cascade off soaring granite cliffs into flowering mountain meadows, where groves of pine, fir and oak shade the banks of a meandering river and where life all around is in harmony. Such a scene greeted naturalist John Muir upon his first visit to Hetch Hetchy Valley, which he called "one of nature's rarest and most precious mountain temples." Today this glory is long gone. Hetch Hetchy now serves as a giant storage tank for the San Francisco Bay area, and lies entombed under 300 feet of water.

In one of its first official acts to protect nature, the U.S. Congress preserved Hetch Hetchy Valley in 1890 as part of Yosemite National Park. But in 1913, after a bitter public debate, Congress sacrificed Hetch Hetchy: it allowed the Tuolumne River to be dammed at the valley's narrow western end, and the valley to then be inundated with 117 billion gallons of water. The proceedings that culminated in the creation of this reservoir marked a turning point in the nation's attitude toward natural resources. In *Wilderness and the American Mind,* Roderick Nash notes, "For three centuries, [Americans] had chosen civilization without any hesitation. By 1913 they were no longer so sure."

FIGURE 1-1
Hetch Hetchy Valley location within Yosemite National Park



While Hetch Hetchy's O'Shaughnessy Dam—the only major dam ever built within a national park—has long been justified as an irreplaceable component of San Francisco's water-supply system, the controversy surrounding its existence has never disappeared. And now an historic opportunity has arisen to revisit that nearly century-old decision. As San Francisco embarks on a $3.6 billion program to upgrade its water system, the time is right for a rigorous exploration of alternative water-supply options. The alternatives outlined in this report, we assert, could cost-effectively replace the water and power provided by the Hetch Hetchy Reservoir and allow the valley to be restored, bringing one of America's most splendid places back to life.

Paradise regained, step by step

In 1987, Donald P. Hodel, Secretary of the Interior under President Reagan, proposed dismantling O'Shaughnessy Dam, and in a report published a year later, the National Park Service examined a range of alternatives for restoring the valley. The report concluded that after draining the reservoir over a five-year period, relatively few sediments would remain. Before long, the Tuolumne River would reoccupy its original channel, and native vegetation could be planted alongside. Five years later, small mammals, amphibians and reptiles once prevalent in the area would have returned to the valley, and within 10 years its meadows would be restored with native plant communities. Over a 50-year period, vegetative cover would be complete and recolonization of animals and re-establishment of habitat would continue. Within a century, the conifer forest would closely resemble that of the Yosemite Valley; ponderosa pines and incense cedars, for example, would be 125 to 150 feet high (see *Restoring Hetch Hetchy: a timeline*).

At present, however, the Hetch Hetchy Reservoir is a major component

Restoring Hetch Hetchy Valley: a timeline

Five years: As areas become exposed and are planted annually, vegetation will rapidly cover the valley floor. Within the first few years, grasses, sedges and rushes will appear. In those areas planted during the first year, conifers and black oaks will reach heights of 15 feet and 6 feet, respectively. Streamside habitat consisting of willow thickets and alders will begin to return, both naturally and through planting efforts. As the water level goes down, small mammals, amphibians and reptiles will explore the valley. As herbaceous forage becomes available and the dry valley floor provides travel paths, black bear and deer will begin to use the valley; meanwhile, populations of bald eagles will increase.

10 years: Plant communities will resume their original patterns; for example, meadows will again appear as meadows. In the higher elevations of the valley, the thin layer of sediments will be eroded, resulting in coarser soils and therefore restoration of more natural habitats. Streamside habitats will feature willow thickets and alder clumps. Small mammals, amphibians and reptiles will reoccupy the valley, with those species faced with physical barriers receiving assistance. As foraging and breeding habitats for mammals become available, populations of predators and birds will increase.

50 years: Boundaries for most plant communities will stabilize, in close resemblance to those originally present in Hetch Hetchy Valley. Prescribed burning, initiated after 20 years, will prevent excessive conifer encroachment on oak woodlands and meadows, thereby maintaining a more natural composition of species. Suitable habitat for peregrine-falcon prey, which decreased with the loss of the reservoir, will completely recover, and deer fawning will begin in the valley.

100 years: The conifer forest will closely resemble that of the Yosemite floodplain. Ponderosa pines and incense cedars will be 125 to 150 feet high, and maturing oak woodlands will be present. In general, animal population and distribution will closely approximate the historical setting.

150 years: The entire valley will very much resemble the pre-flooded valley, and forest and woodland communities will be nearly mature.

Note: This information summarizes the moderate-management scenario of the National Park Service's 1988 report *Alternatives for Restoration of Hetch Hetchy Valley Following Removal of the Dam and Reservoir.*

of a water system that supplies 2.4 million people. This water, renowned for its high quality, receives only minor treatment and is one of the very few unfiltered systems still permitted to operate in the United States. Releases from the reservoir also generate valuable hydropower. Thus the first step to restoring Hetch Hetchy Valley is the development of a plan to replace the reservoir's significant water-supply, water-quality and hydropower benefits. This report documents a systematic exploration of that challenge and offers a set of explicit recommendations for meeting it.

This report shows how a few key projects within San Francisco's $3.6 billion Capital Improvement Program could not only improve the City's ability to deliver water but also allow for the ultimate restoration of Hetch Hetchy Valley. These projects include the expansion of the Calaveras Reservoir near Fremont to more than four times its present size, an increase in the capacity to move water across the San Joaquin Valley, and the enlargement of the Sunol Water Treatment Plant.

Organization of the report

Following this introduction's brief discussion of the purpose and scope of our study, several chapters provide background information on Hetch Hetchy Valley and the water and power services that it now provides. Chapter 2 presents an overview of the natural history of the valley, the events that led to its damming and flooding, and the emerging discussion on restoring it. Chapters 3 and 4 outline California's current water and power systems, respectively, and describe options for meeting projected increases in demand. Chapter 5 surveys the Tuolumne River and its uses through two sets of discussions: the current water-supply and hydropower operations of the San Francisco Public Utilities Commission (SFPUC); and the recreational and ecosystem-restoration activities related to the river.

The remainder of the report presents and analyzes ways of restoring Hetch Hetchy Valley. Chapter 6 provides cost estimates of alternative components of water-supply systems. Chapter 7 presents results from computer-based simulations of the SFPUC's operations that show how incorporating these alternatives can obviate the need for the Hetch Hetchy Reservoir while maintaining, even improving, the reliability and safety of the water supply. Chapter 8 then offers a brief overview of water-quality and treatment issues, together with estimates of the unit costs of treating water from alternative sources. Chapter 9 explains how restoring Hetch Hetchy Valley would affect power generation and revenues, considers available substitutes for the forgone energy resources, and provides estimates of replacement costs. Chapter 10 integrates the cost estimates developed in the preceding chapters, and presents a range of discounted present values for the total cost of replacing present water and power services. Chapter 11 discusses this project's legal and institutional ramifications. Finally, Chapter 12 summarizes our findings and recommendations, and proposes a public process that the SFPUC and other stakeholders, with the support of state and federal governments, should follow in developing a restoration plan.

Scope of the report

This report is intended to lay the groundwork for further investigation into restoring Hetch Hetchy Valley. While it does not claim to analyze all possible alternatives, the report concentrates on what we consider to be the most viable—those that maintain the use of Tuolumne River water but divert it farther downstream, outside the boundaries of Yosemite National Park.

Our analysis considers both current delivery objectives and the SFPUC's initially projected increased delivery objectives for 2030. The City of San Francisco and its customers are presently engaged in comprehensive analyses of the potential for increased implementation of proven water-use efficiency measures to decrease future demand. The results of these analyses should guide the development of a cost-effective and environmentally-protective water supply system.

Beyond referring to the 1988 report of the National Park Service, this study does not address the actual physical restoration of Hetch Hetchy Valley or how to manage it afterward. Similarly, analysis of the restored valley's significant economic impacts in general, or of its value to surrounding communities in particular, is outside the study's scope. Rather, this report examines the complex—but surmountable—water and power issues that present the most obvious political obstacles to restoring Hetch Hetchy Valley.

While the main body of the report is the work of Environmental Defense staff, three independent consultants helped with key elements. Schlumberger Water Services analyzed the basic engineering components of conveyance and storage alternatives, and assisted with hydrologic modeling of alternative water-supply options. Eisenberg Olivieri & Associates assessed how the SFPUC might handle water if it were diverted at locations farther downstream. Finally, Somach, Simmons & Dunn provided an initial overview of the complex legal issues surrounding water rights, including aspects of the 1913 Raker Act that authorized the construction of O'Shaughnessy Dam within Yosemite National Park. Each consulting group prepared a full account of its findings, which are included as appendices to this document; Environmental Defense summarizes those findings within the main text.

An opportune time for collaboration

This report shows that there are a number of feasible and cost-effective alternatives to storing water in Hetch Hetchy Valley. Moreover, Environmental Defense believes that the present—as San Francisco embarks on a fundamental upgrade of its water system—is an opportune time to consider these alternatives.

Any effort to bring back Hetch Hetchy Valley must respect the rights and concerns of people who use the Tuolumne River, as well as of those who would revere a restored valley. Crafting a solution acceptable to all will require a cooperative effort among local, state and federal agencies and the public. All parties must work to fairly allocate costs, not only for replacing the water and power benefits currently provided by O'Shaughnessy Dam but for restoring and managing the valley itself.

Restoring Hetch Hetchy Valley after nearly 100 years would recover one of our planet's geological wonders—a unique natural habitat for wildlife and an oasis for people in the midst of the rugged Sierra Nevada. A restored valley would also relieve the pressure on the much loved but highly congested Yosemite Valley 15 miles to the south. With support from a dedicated public, some imagination, and a willingness by government officials at all levels to work together, we believe that Yosemite's long-lost twin can be brought back to its natural glory.

CHAPTER 2

Hetch Hetchy: past, present and future

Millions of years ago, a series of upheavals deep inside the earth thrust up California's Sierra Nevada Mountains. Over time, rivers then carved narrow canyons into the rock. Glaciers widened and deepened some of these canyons, leaving the tributaries' less-deeply-incised valleys suspended above vertical cliffs. Today, those "hanging" valleys harbor lakes, and streams cascade from the cliffs.

The most spectacular legacies of the Sierra's glacial past lie in Yosemite National Park. Particularly revered is Yosemite Valley, world-famous for its mountain meadows nestled below sheer rock faces and thundering waterfalls. Yosemite Valley draws more than 3 million visitors each year, but few of them know that *two* magnificent valleys once graced the park. Hetch Hetchy Valley, Yosemite's nearby twin, provided a similarly spectacular setting. But Congress allowed Hetch Hetchy's Tuolumne River to be dammed in 1913, and today the valley—serving as a storage tank for the San Francisco Bay Area—lies submerged beneath 300 feet of water.

Yosemite's residents

Elevations in Yosemite National Park range from 2,000 to more than 13,000 feet, providing habitat for a vast array of plants and animals. Vegetation varies dramatically, from rugged chaparral in the lower elevations to high-country alpine meadows, and the park harbors more than 160 rare plants. Yosemite also hosts more than 300 species of mammals, such as black bears, bighorn sheep and bobcats, and a wide variety of bird species that includes the white-headed woodpecker, northern goshawk and spotted owl.

Yosemite attracted its first human residents some 7,000 to 10,000 years

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Tueeulala and Wapama Falls descend from cliffs on the north side of Hetch Hetchy Valley. John Muir described Tueeulala Falls as excelling even Yosemite's Bridalveil Falls "in height and airy-fairy beauty and behavior."


BANCROFT LIBRARY

Hetch Hetchy Valley as its original Native American residents saw it for thousands of years before Europeans came to the Americas.

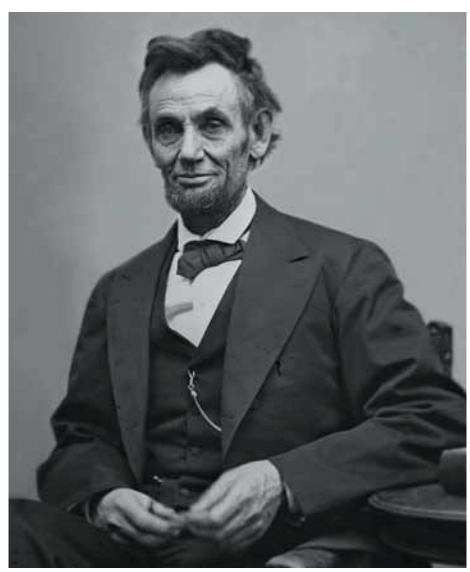
ago. By the time European colonists landed in the New World, the Ahwahneechee Indians thrived in Yosemite Valley and surrounding areas. They named the area Hetch Hetchy after the native grass that grew in the valley.

The 1849 gold rush brought large numbers of prospectors to the Sierra Nevada, and they quickly came into conflict with the native people. In 1851, one year after statehood, California formed the Mariposa Battalion to bring an end to the "Mariposa Indian War." Soon afterward, the Indians left Yosemite and dispersed into the Mono Basin and other areas beyond the mountains.

The campaign to preserve Yosemite

Through the images produced by artists, photographers and writers, awareness of Yosemite's wonders spread. Increasing numbers of people made their way to the area on foot and horseback,[1] and the growing population began to develop the region and compromise its natural beauty. Homes and hotels sprang up, farmers created fields and orchards, and livestock grazed in the meadows.

Naturalists, artists and other respectful visitors began to advocate for protections. In fact, the national debate about preserving land in national parks began with Yosemite. Israel Ward Raymond, a representative of the Central American Steamship Line, rallied a


LIBRARY OF CONGRESS

Less than a year after delivering the Gettysburg Address, Abraham Lincoln signed an historic bill to protect parts of Yosemite.

WADSWORTH ATHENEUM

Before Hetch Hetchy was the center of controversy, and even before it was made accessible to the public, the valley was appreciated by some of the nation's most renowned landscape artists, including painters Albert Bierstadt and William Keith and photographer Carleton Watkins. They traveled miles through the wilderness and often spent weeks camped in Hetch Hetchy in order to capture the valley's splendor. Their works, including the above Bierstadt painting "The Hetch Hetchy Valley", are still treasured today.

small but persistent group to lobby the U.S. Congress to shelter Yosemite from unrestrained development.

Persistence paid off. In the midst of the Civil War, with Confederate troops advancing on Washington, President Abraham Lincoln took time to consider the future of faraway Yosemite. On June 30, 1864, inspired by glowing reports of the area's beauty, Lincoln signed the Yosemite Act to preserve the valley for "public use, resort, and recreation . . . inalienable for all time."[2]

But many soon recognized that in order to preserve the character of the region, additional land would have to be set aside. Writer-naturalist John Muir and others tirelessly lobbied Congress over the issue. In March of 1890, a bill was introduced that called for land surrounding the Yosemite Valley, including Hetch Hetchy Valley, to be designated a protected national park. The bill passed easily, and President Benjamin Harrison signed it on October 1, 1890, thereby creating Yosemite National Park.

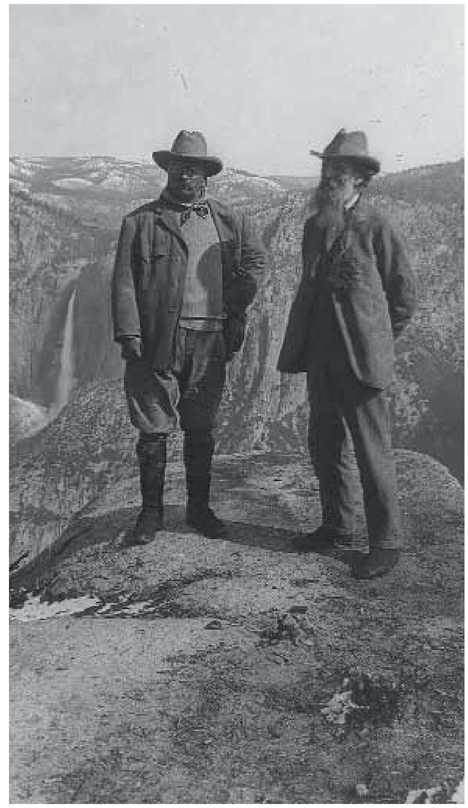
The plan to dam Hetch Hetchy Valley

President Harrison's signature was barely dry, however, when a proposal to exploit the young national park emerged. The booming City of San Francisco had been eyeing the Sierra Nevada Mountains, and especially Hetch Hetchy Valley, as a potential source of fresh water since the 1880s. The City petitioned the federal government twice, in 1903 and 1905, to dam the Hetch Hetchy gorge, but President Theodore Roosevelt's administration denied both proposals as "not in keeping with the public interest."

A bitter dispute followed, with Muir leading the fight against the dam. "Dam the Hetch Hetchy?" he famously declared. "As well dam for water tanks the people's cathedrals and churches, for no holier temple has ever been consecrated by the

NATIONAL INFORMATION SERVICE FOR EARTHQUAKE ENGINEERING, U.C. BERKELEY

The 1906 earthquake's damage to San Francisco's pipes-not any inadequacies in its reservoirs-resulted in a lack of water to fight the devastating fire.



LIBRARY OF CONGRESS

John Muir consistently and vigorously opposed damming Hetch Hetchy. Teddy Roosevelt struggled between his commitments to preserving wild places and supporting development, but eventually declared that Hetch Hetchy Valley should be protected and "the scenery kept wholly unmarred."[8]

heart of man." The battle over Hetch Hetchy marked the beginning of a new era: as the forces behind unfettered development clashed with conservationists, the environmental movement was born.[3]

The turning point came on April 18, 1906, when a powerful earthquake struck San Francisco, followed by a devastating fire. As firefighters struggled to contain the blazes, hydrants went dry. In actuality, the City's reservoirs held ample supplies, but the Spring Valley Water Company's water pipes had failed because of quake damage.[4] Even though water supply wasn't the problem, the pro-dam faction saw an opportunity to exploit the nation's sympathy for the young metropolis. In 1908 the Department of Interior reversed its earlier position and elected to reconsider San Francisco's request for rights-of-way to develop the Hetch Hetchy project in Yosemite National Park.

Preservationists were outraged at the prospect of such large-scale destruction within a national park. Muir vowed to keep the protest letters flying to Washington "as thick as snowflakes,"[5] and opposition to damming Hetch Hetchy gained momentum nationwide. More than 100 newspapers (see *The Hetch Hetchy Grab,* page 9) decried the project. In 1913, the *New York Times* printed six anti-dam editorials, lambasting "San Francisco Philistines who know how to 'improve' the handiwork of the Creator." [6] Unmoved, supporters of the dam dismissed the preservationists as "short-haired women and long-haired men."[7]

Despite the public outcry, the efforts of John Muir and others, and the existence of feasible water-supply alternatives, Congress upheld the 1908 permit and passed the Raker Act in 1913, authorizing San Francisco to begin building the dam. The *Times* railed: “The battle was lost by supine indifference, weakness and lack of funds.” Legend holds that Muir died of a broken heart over the loss of the valley.

BULLETIN No. 1

NATIONAL COMMITTEE FOR THE PRESERVATION OF THE YOSEMITE NATIONAL PARK

The members of the National Committee, which includes representatives of every State and of a large number of important Institutions and Societies throughout the Country, will be published in Bulletin No. 2.

Robert Underwood Johnson, Chairman, 327 Lexington Avenue, New York

Edward Hagaman Hall, Secretary and Treasurer, Room 808, Tribune Building, New York

“The Board [of Army Engineers] is of the opinion that there are several sources of water supply that could be obtained and used by the city of San Francisco and adjacent communities to supplement the nearby supplies as the necessity develops. From any one of these sources the water is sufficient in quantity and is, or can be made, suitable in quality. While the engineering difficulties are not insurmountable, the determining factor is one of cost.”—*Official Report of the Advisory Board of Army Engineers.*

THE HETCH HETCHY “GRAB”

Who Oppose It and Why

THE PRESS OVERWHELMINGLY AGAINST IT

Outside of San Francisco these newspapers and other organs of public opinion are on record against the plan to destroy the great Hetch Hetchy Valley by flooding it and to deny the public the free access it now has to the northern half of the wonderful Yosemite National Park, it being confessed that the city can get its supply elsewhere “by paying for it.” Additions to this list are continually being made.

Boston Christian Science Monitor
Boston Transcript
Boston Post
Boston Record
Boston Herald
Boston Advertiser
Springfield Republican
Springfield Union
Lowell Citizen
Newburyport News
Manchester (N. H.) Mirror
Burlington (Vt.) News
Burlington Free Press and Times
Providence Journal
Providence Tribune
Hartford Times
New Haven Register
Waterbury (Conn.) American
Worcester Gazette
New Bedford Mercury
New Bedford Standard
Portland (Me.) Press
Bangor Commercial
Fall River News
Ansonia (Conn.) Sentinel.
New York Times
New York Tribune
New York World
New York Call
New York Telegraph
New York Evening Post
Brooklyn Standard Union
Brooklyn Eagle
Albany Journal
Buffalo Commercial
Troy Record

Utica Observer
Utica Gazette
Rochester Times
Rochester Union Advertiser
Rochester Chronicle
Syracuse Post-Standard
Poughkeepsie Eagle
Poughkeepsie Enterprise
Jersey City Journal
Newark Morning Star
Camden Telegram
Amsterdam (N. Y.) Record
Philadelphia Ledger
Philadelphia Record
Philadelphia Telegraph
Philadelphia Inquirer
Scranton Times
York (Pa.) Gazette
Allentown Call
Baltimore American
Baltimore Evening Sun
Cleveland Plain Dealer
Atlanta Journal
Mobile Register
Macon (Ga.) Telegraph
Jacksonville (Fla.) Times
Jackson (Miss.) Ledger
Dallas (Texas) Viewpoint
Nashville Democrat
Memphis Appeal
Louisville Courier-Journal
Lexington (Ky.) Leader
Cincinnati Journal and Messenger
Dayton (Ohio) News
Akron Journal

The Flint (Mich.) Journal
Ft. Wayne News
Indianapolis News
Chicago Inter Ocean
Milwaukee Press
Milwaukee Journal
Milwaukee News
Oshkosh Northwestern
Davenport (Iowa) Democrat
Sioux City Tribune
Burlington Hawkeye
Minneapolis Journal
Minneapolis Tribune
St. Paul Pioneer Press
Lincoln (Neb.) Journal
Denver Republican
Denver Rocky Mt. News.
Salt Lake Republican
Seattle Times
Seattle Post Intelligencer
Tacoma Daily News
Portland Oregonian
Oregon Journal
San Francisco Wasp
San Francisco News Letter
Pasadena News
World's Work
The Independent
The Outlook
Outdoor World and Recreation
Christian Endeavor World
Out West Magazine (Cal.)
Review of Reviews
The Century,
and many others.

ORGANIZATIONS ON RECORD AGAINST IT

Two-thirds of the Sierra Club of San Francisco
Society for the Preservation of National Parks (Eastern and Western Branches)
American Civic Association
American Scenic and Historic Preservation Society
American Alpine Club
Mazamas of Portland, Oregon

Mountaineers of Seattle
Chicago Geographical Society
Zoölogical Society of New York
Playground Association of America
General Federation of Women's Clubs
California and Other State Federations of Women's Clubs and others.

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More than 100 newspapers nationwide decried the plan to build a dam in Yosemite National Park.

A natural wonder succumbs to a feat of engineering

Damming Hetch Hetchy Valley and building a system to carry water 160 miles from the Sierra Nevada to San Francisco was a vast undertaking. Not only were the challenges of the engineering structures daunting in and of themselves, but also the project required transporting supplies through rugged mountainous areas where few roads existed.

San Francisco mayor Jim Rolph tapped Michael O’Shaughnessy-an abrasive but accomplished engineer whose work on the Southern Pacific Railroad, Marin County’s Alpine Dam, and other large projects had established his skills and reputation-to lead the effort (see *Michael “The Chief” OShaughnessy: a man of action*, page 10). It took O’Shaughnessy and his workers 10 arduous years to complete the 312-foot-high dam; the first stage of the project, a 68-mile supply railroad, went into operation in 1918, carrying 400 tons of cement a day to the dam site. During his decade of work there, O’Shaughnessy developed an appreciation for Hetch Hetchy Valley, even using a photo of it in his 1919 Christmas card. However, sentimentality seems not to have impeded him moving ahead with the project. In 1923, the City held an opening ceremony for the dam, which it named after its chief engineer.

The debate re-emerges

The controversy provoked by the dam never truly disappeared. In 1921, Congress passed a law prohibiting the issuance of licenses for hydroelectric projects within national parks, unless authorized by Congress. Later, in 1992, the law was amended to further restrict new projects within the National Park system. In 1987 Donald P. Hodel, President Reagan’s Secretary of the Interior, proposed removing the dam and restoring the valley.

Michael "The Chief" O'Shaughnessy: a man of action

The brains behind the massive engineering project to dam Hetch Hetchy Valley, Michael O'Shaughnessy, was a combative, colorful character and a skilled engineer. To his workers he was known simply as "The Chief." To others he was "a man of action" who would stop at nothing to achieve his ends. In addition to conceiving the Hetch Hetchy project, O'Shaughnessy lobbied Congress tirelessly on its behalf. During one particular week, the Senate questioned him continuously from Monday morning until late Saturday night. Many who sat through the debates came just to see The Chief in action.

Born and raised in Ireland, O'Shaughnessy trained as a civil engineer in his home country and departed, shortly after graduating, for San Francisco. There he built an impressive engineering reputation with projects such as the Mill Valley street system and the Marin County Alpine Dam, and with his work on the Southern Pacific, Sierra Valley and Mohawk railroads.[9]

San Francisco Mayor Jim Rolph appointed O'Shaughnessy the City's chief engineer in 1912. He held this office until 1932, completing projects such as the Twin Peaks tunnel, the San Francisco Municipal Railway, the Great Highway from the Cliff House to Sloat Boulevard, and, his largest project, the O'Shaughnessy dam.[10]

The dam posed several engineering challenges because of Hetch Hetchy Valley's remote location in the Sierra Nevada. Not only did O'Shaughnessy have to build a massive dam and power plant, he also had to oversee the construction of miles of roads, railroads, tunnels and aqueducts to move the needed water and supplies.

Despite his commitment to its success, O'Shaughnessy appeared ambivalent at times about the project. Even before the Raker Act authorizing the dam had passed, O'Shaughnessy acknowledged the binding nature of the investment in a letter to Mayor Rolph dated June 14, 1912. "The City has spent so much money under government rights," said O'Shaughnessy, "that they cannot now abandon the Tuolumne for another and even more economical Sierra Project."[11] In 1919, as construction of the dam began in earnest, he used a dramatic image of the valley as a Christmas card.

Nonetheless, O'Shaughnessy, the "man of action," completed the dam—and its complex delivery system of aqueducts, pipes and tunnels—with the focus and skill for which he was renowned.[12] He died in 1934 at the age of 70, only days before the first Hetch Hetchy water from behind the O'Shaughnessy Dam arrived in San Francisco.

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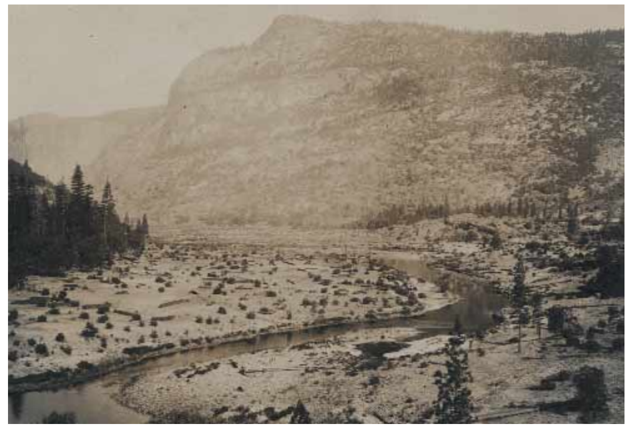
Even hard-bitten chief engineer Michael O'Shaughnessy, for whom the dam is named, found Hetch Hetchy Valley enchanting. This 1919 Christmas card, sent to his friends and acquaintances, features its unique beauty.



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After the passage of the Raker Act, it took 10 years to build O'Shaughnessy Dam. Shown above: pre-dam panorama of Hetch Hetchy Valley; Hetch Hetchy Railroad, built to bring necessary materials to the remote dam site; the valley floor cleared of trees; construction in progress; dedication of O'Shaughnessy Dam in 1923; the completed reservoir (where public boating has never been allowed).

A year later, the Bureau of Reclamation released its report, *Hetch Hetchy Water and Power Replacement Concepts*, and the National Park Service issued a study evaluating the possibilities for restoring the valley's ecosystem.

Now the debate over using a national park for municipal water supply has re-emerged. As San Francisco launches a major renovation of its water system, there is a once-in-a-lifetime opportunity to return Hetch Hetchy to the public trust, and to its natural splendor.

In its 1988 study, the Bureau of Reclamation wrote: "Could the City of San Francisco receive a comparable water and power supply from other sources? Could the Hetch Hetchy Valley be restored as part of the living heritage of our national park system? In a world of diminishing natural resources, what is the highest use of the valley? These are questions worth asking." Environmental Defense agrees, and we believe that their answers, and the ultimate results of the sound and inspired programs potentially engendered, would very much delight John Muir and his kindred spirits past, present and future.

CHAPTER 3
California water summary

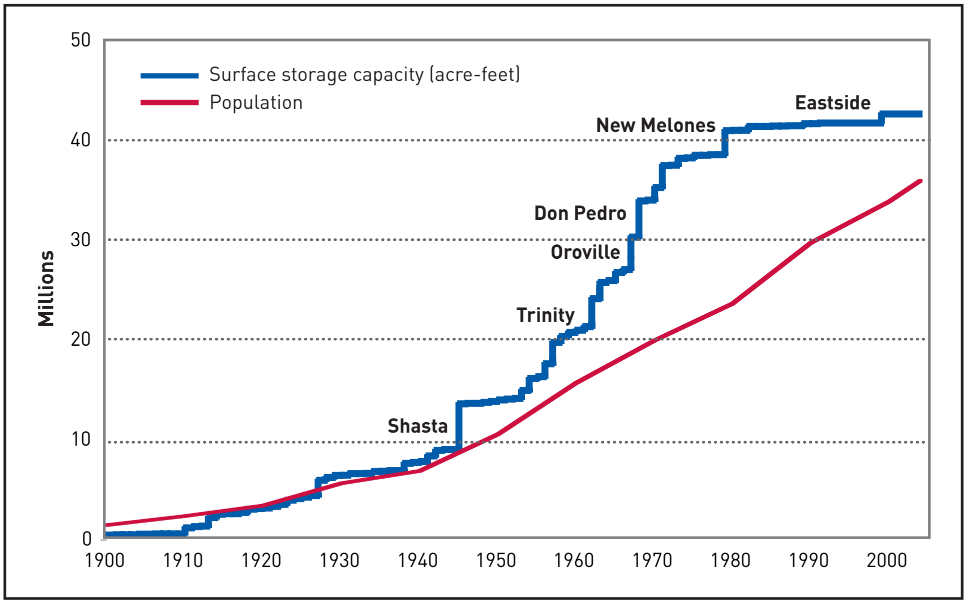
California is the most populous and agriculturally productive state in the nation, largely due to vast irrigated basins spanning the interior of the state. Californians value their natural environment and are increasingly selective in approving projects that might degrade it.

Residents are especially sensitive about further depleting the state's water resources. But because California is semi-arid, like much of the American West, its communities and economy depend on secure, safe, and reliable water supplies. For most of the past century, ensuring this reliability meant building a vast network of dams and canals to move water from rivers to distant farms and cities (Figure 3-1).

California now has more than 1,000 dams, with a combined water-storage capacity of over 40,000,000 acre-feet. Hetch Hetchy Reservoir, which today is the twentieth largest in the state, holds only 360,000 acre-feet (Figure 3-2)—although it was once the largest reservoir in the entire Central Valley watershed. Lying downstream of Hetch Hetchy and holding almost six times as much water, Don Pedro Reservoir is one of California's largest. The Turlock Irrigation District, the Modesto Irrigation District and the San Francisco Public Utilities Commission all store water in Don Pedro. San Francisco alone can store up to 740,000 acre-feet there, more than twice the maximum storage of Hetch Hetchy Reservoir.

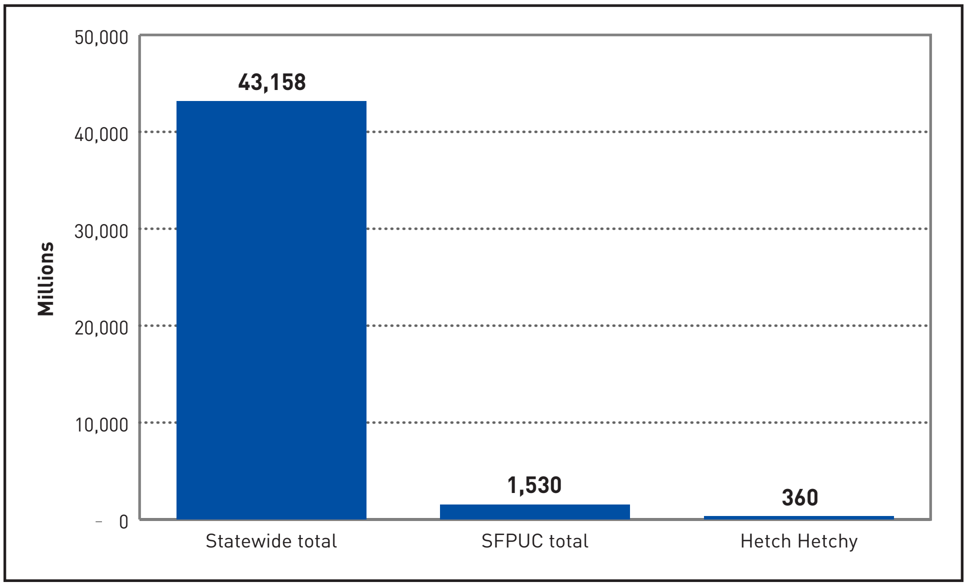
> Water volumes are often measured in **acre-feet.** One acre-foot (326,000 gallons) is enough water to satisfy the average annual needs of two to four families.

FIGURE 3-1
Surface water development in California, 1900–2000



This graph traces the course of surface-water development over the 20th century, including the dam-building boom in the decades that followed World War II. With few locations left for which dams are practical, many water agencies have found the development and management of groundwater basins to be an effective alternative. Source: California Department of Water Resources

FIGURE 3-2
Comparative surface storage volumes



While the Hetch Hetchy Reservoir provides significant benefits, it is a small part of the statewide water-storage picture. Hetch Hetchy accounts for less than 25 percent of SFPUC's total storage.
Source: California Department of Water Resources and Bureau of Reclamation

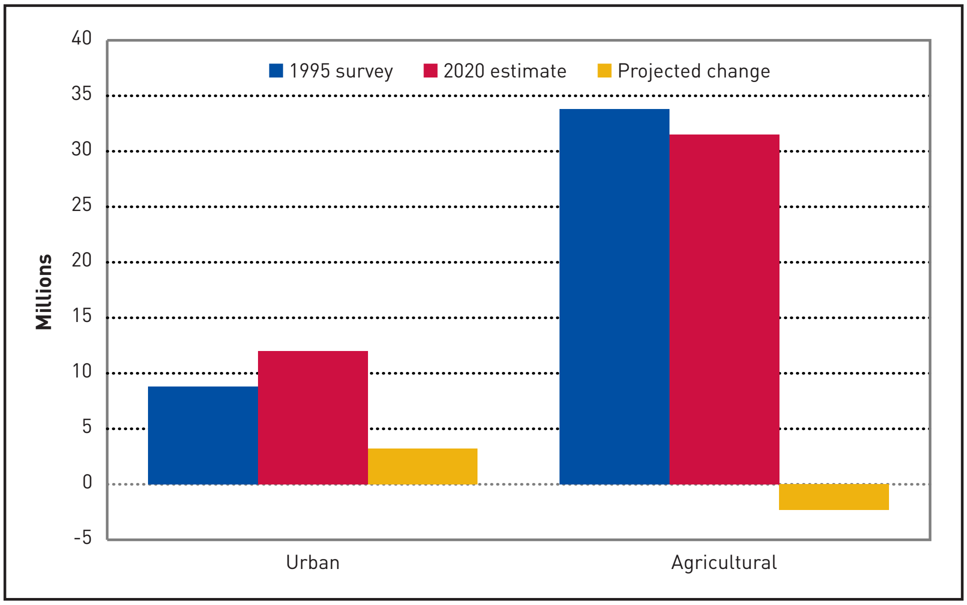
Today there are few practical opportunities to build new dams that would impound the natural flow of a large river. Most of California's major rivers are already dammed, protected by law, or too remote to be economically developed. But innovative water managers are finding that they can extend supplies in a variety of other ways, including increased efficiency, recycling, local storage, groundwater management, and transfers and exchanges with other agencies that have different sources and needs.

This chapter provides an overview of current trends among California's municipalities and farming communities in how they meet their customers' water needs, including the recent approaches taken by urban water agencies. Context is thus established for the water-supply components, presented in Chapter 6, offered as possible alternatives to the Hetch Hetchy Reservoir.

Moving water to cities and farms in California

In California, precipitation occurs disproportionately in the north, while most cities and farms are located in the southern two-thirds of the state. The State Water Project and the federal Central Valley Project store winter storm runoff and spring snowmelt in a series of large dams in northern California on the Sacramento, Feather, Trinity, and American Rivers. Releases from these reservoirs pass through the Sacramento-San Joaquin Delta, where as much as 6,000,000 acre-feet per year of water are diverted to cities and farms in central and southern California via an intricate system of pumps, pipes and canals. Southern California also receives significant supplies from the Colorado River through the All-American and Coachella Canals and the Colorado River Aqueduct, though their supplies have recently been cut.

FIGURE 3-3
Projected changes in statewide water use (1995–2020)



California's State Water Plan projects increases in urban water use that are partially offset by slight decreases in agricultural use.
Source: California Department of Water Resources

Agricultural water-use trends

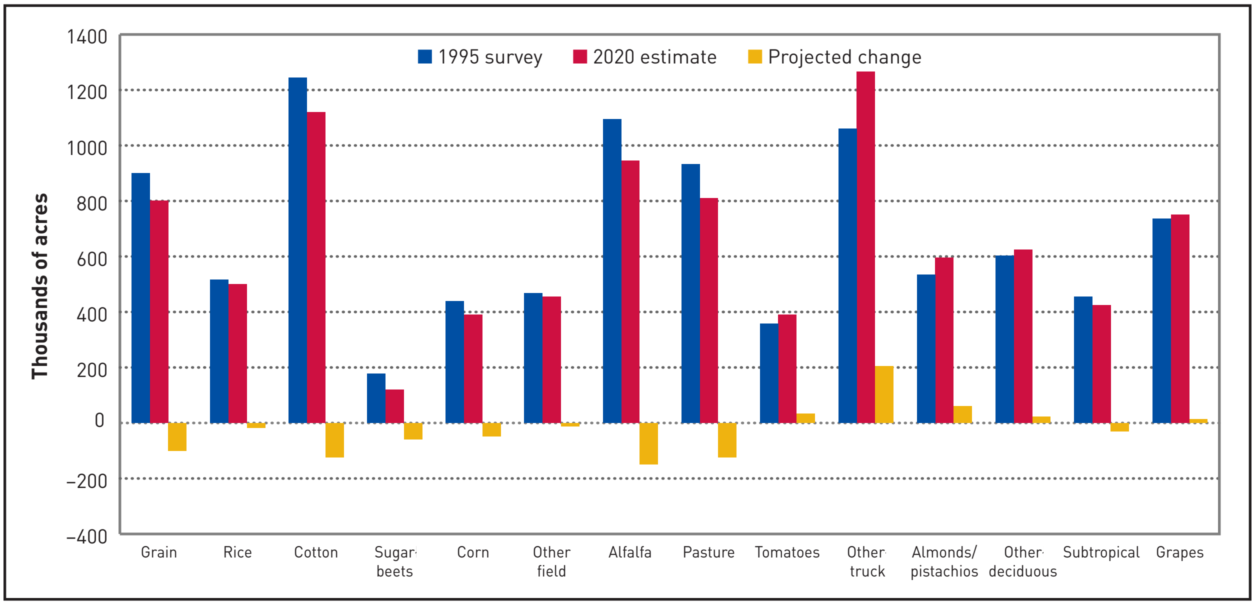
Statewide, approximately 80 percent of developed water in California is used by irrigated agriculture. Over the next 30 years, as cities, suburbs and rural communities continue to grow, a slight reduction in the agricultural proportion is expected.[1] Some of this reduction is attributable to the Metropolitan Water District of Southern California, which will be taking a greater share of State Water Project (SWP) supplies, leaving less available for the SWP's agricultural contractors. In addition, agricultural districts are finding that they can improve water-use efficiency or switch to crops that use less water. Some of them have profited from this strategy by selling or leasing unneeded water for urban use or to provide environmental benefits.

STUART WOOLF

CALIFORNIA DEPARTMENT OF WATER RESOURCES

Left: Farms throughout California are increasingly adopting water efficient technologies, such as above ground drip irrigation, as used on the Central Valley farm pictured above. Right: California is the top agricultural producer in the nation contributing over half of the nation's nut, fruit, and vegetable production.

FIGURE 3-4
Projected change in crop acreage (1995–2000)



The California State Water Plan projects adjustments in various crop acreages between 1995 and 2020. The largest projected decrease is for alfalfa, a crop that uses up to 7 acre-feet of water per acre annually, depending on location. The largest increase is for "other truck" crops (such as vegetables and melons) that typically use less than one-half of the water per-acre required by alfalfa, even as they result in greater revenue and employment.[2]
Source: California Department of Water Resources

To compete in today's global economy, farmers have needed to become increasingly sophisticated. They must carefully determine which crops to grow each year, based on factors ranging from water availability and soil quality to international market trends. California's State Water Plan thus predicts overall shifts within agriculture over the next few decades, in response both to anticipated competition from other regions and the future costs of production (Figure 3-4). In many areas, farmers have already gone "high-tech"—they are using Global Positioning Systems, for example, to better manage their fields. This technology complements other efficiency investments, such as drip irrigation, which help farmers grow more for the same or lesser amounts of water.

Urban water use

In 2000, California's cities used about 8.7 million acre-feet of water.[3] With the exception of multi-year droughts, adequate supplies have been available to meet demands despite a rapidly growing population. In fact, since the late 1970s, urban water use has increased only moderately as urban agencies throughout the state have found new ways to provide safe, clean and reliable water supplies for their constituents. Increasingly, these agencies are turning from remote dams and reservoirs to a host of other alternatives that are more cost-effective, more reliable, and usually far less environmentally damaging. They include:

- Building local reservoirs to store supplies, whether local and imported
- Transfers, either in all years or in dry years, from agricultural districts
- Surface and groundwater exchanges with agricultural districts
- Increased water-use efficiency (also known as conservation or demand-side management)

- Recycling and wastewater reclamation
- Desalination

LOCAL STORAGE

In the last 10 years, two new reservoirs have been built by California water agencies to better serve local customers. In 1998, the Contra Costa Water District completed Los Vaqueros Reservoir (100,000 acre-foot capacity). In 2003, the Metropolitan Water District of Southern California completed the Eastside Reservoir (800,000 acre-feet). Both are "off-stream" reservoirs that do not dam major rivers but are filled primarily in wet years with imported supplies, thereby providing increased reliability in dry years.

San Francisco's proposal to expand the capacity of its Calaveras Reservoir from 97,000 acre-feet to 420,000 acre-feet is in a similar spirit. If Calaveras Reservoir were to grow to that size, it would need to include infrastructure for pumping surplus (wet-year) Tuolumne River supplies into the reservoir for use in dry years.[4]

TRANSFERS

Water transfers, put simply, are one water user's sales to another. Historically, municipal agencies and agricultural districts developed water supplies independently, with few market-based dealings between them. But water managers from the different sectors have learned to implement mutually beneficial transactions. Given the great difference in scale between established agricultural and urban water demands, moreover, transfers to meet moderate growth in the urban sector can be accomplished without major disruption in overall agricultural uses statewide.[5]

Thus short- and long-term water transfers, totaling hundreds of thousands of acre-feet, have annually been occurring between water users.[6] *Water Strategist,* a publication that reports on marketing, legislation, litigation and financial information related to water resources, identified 30 separate transactions, including 7 permanent acquisitions, that took place in California during 2003. In most cases, the buyers were municipal agencies representing large and small cities. The state and federal governments also bought supplies, on behalf of the public, to protect and restore fisheries in the Sacramento-San Joaquin Delta estuary.[7]

Southern California agencies in particular, including the Metropolitan Water District (MWD), have in recent years been actively purchasing both Central Valley and Colorado River water supplies through a variety of means, including:

- A 1988 agreement between MWD and the Imperial Irrigation District (IID) for 90,000-110,000 acre-feet per year in exchange for funding a conservation investment program within IID.
- A 2002 agreement with Sacramento Valley parties that would provide MWD and other agencies that receive supplies from the Delta with at least 92,500 acre-feet (and up to 185,000 acre-feet) at costs ranging from $50 per acre-foot in above-normal years to $125 in critically dry years.
- A 2003 agreement between the San Diego County Water Authority (SDCWA) and IID for a long-term agreement to purchase 200,000 acre-feet per year from IID at a starting price of about $260 per acre-foot.
- A 2004 agreement between the Palo Verde Irrigation District (PVID) and MWD to purchase up to 111,000 acre-feet per year from PVID farmers for approximately $100 per acre-foot. The deal also includes a one-time initial payment of approximately $500 per acre-foot.

Transfers have the potential to reduce water scarcity. However, like every other

CALIFORNIA DEPARTMENT OF WATER RESOURCES

After years of negotiations, a long-term agreement between San Diego and the Imperial Irrigation District was reached in 2003.

source of water in California, voluntary transfers are frequently accompanied by controversy. Local communities often assert that while water sales may benefit a few local agencies or farmers, the broader community can be harmed through a variety of effects, including depressed agricultural production or depleted groundwater. Both the IID-SDCWA and PVID-MWD agreements noted above include advance commitments to mitigate at least some of these potentially adverse socio-economic impacts.

GROUNDWATER BANKING AND EXCHANGE PROGRAMS

Urban agencies and agricultural districts are beginning to work together to manage groundwater efficiently. Under a typical groundwater banking and exchange program, in wet years a portion of an urban agency's surface water is diverted to an agricultural district, where it can be stored underground (Figure 3-5). In a dry year, some of the agricultural district's surface water is diverted to the urban area to augment the urban area's limited supply, and the

FIGURE 3-5
How a groundwater exchange program works

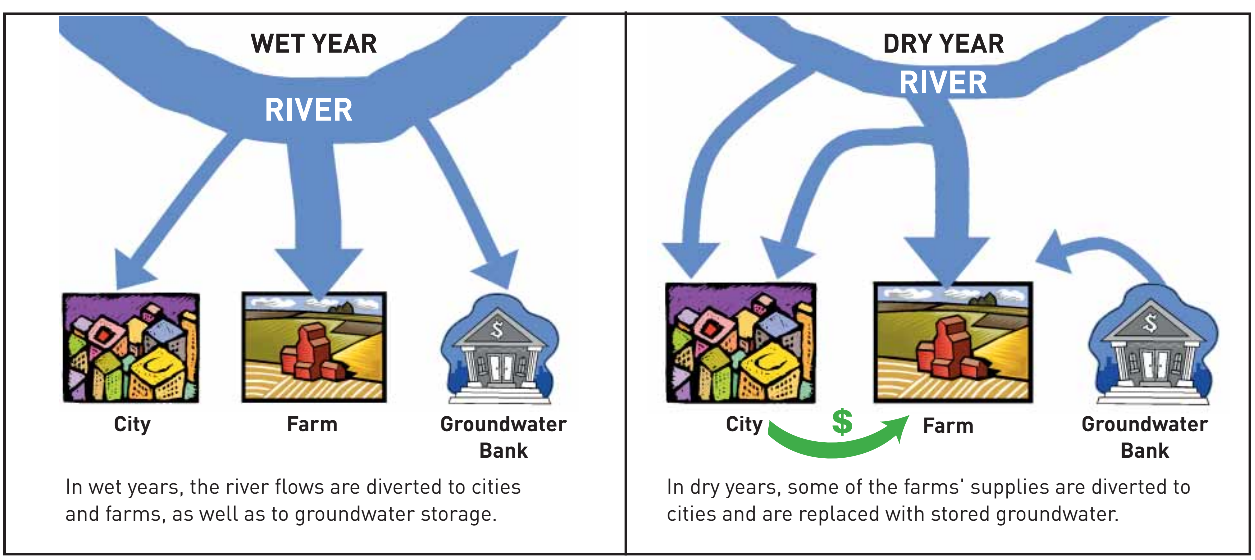


TABLE 3-1
Current groundwater exchange programs

Urban agency	Maximum extraction capacity Thousand acre-feet/year	Maximum storage capacity Thousand acre-feet
Metropolitan Water District	153	700
Santa Clara Valley Water District	78	350
Alameda County Water District	33	150
Zone 7 (Livermore-Amador Valley)	14	65

These programs are currently in place with Semitropic and Arvin-Edison Water Districts. MWD's agreements involve costs of about $300 per acre-foot.[8]

agricultural district can then extract the stored groundwater to supplement its own supply. The frequency of physical exchange under these agreements varies, but additional groundwater is normally pumped in dry years only.

Several Bay Area districts have banked water in the Semitropic Water District in Kern County, and Southern California's Metropolitan Water District has banked water with Semitropic and with the nearby Arvin-Edison Water District as well (Table 3-1).

San Francisco has investigated groundwater-banking alternatives for more than a decade, though has yet to implement any such programs. A 1993 study evaluated 15 separate alternatives, ranking 7 of them as "good" opportunities[9]. San Francisco's Water Supply Master Plan (2000) identifies groundwater-banking opportunities in the Bay Area, the lower Tuolumne watershed and other Central Valley locations as well.

URBAN WATER CONSERVATION

Water agencies throughout California now recognize that assuring a reliable supply includes the management of demand. The combination of new technology, educational opportunities and public sentiment are prompting these agencies to stimulate efficient water use among their customers. Local crises also play a role. In large part as a result of the 1976-1977 and 1987–1992 droughts, many agencies—including the Los Angeles Department of Water and Power and MWD—were driven to increase their investments in water-conserving devices in homes and businesses as well as in educational programs to encourage behavioral changes among urban water users.

For most agencies, however, there is room for improvement. Some Central Valley cities do not even measure a customer's water use. In *Waste Not, Want Not: The Potential for Urban Water Conservation in California* (November 2003), the Pacific Institute estimates that one-third of California's current urban water use—more than 2.3 million acre-feet—can be conserved with existing technology. Though some might believe that an inevitable consequence of improved water-use efficiency is increased urban growth, it should be noted that conservation can provide many environmental benefits. Conserved water may be used to enhance in-stream flows, for example, or play a role in restoring Hetch Hetchy Valley.

In a cooperative effort to increase efficiency, urban water agencies and

The campaign to save Mono Lake included a grassroots effort, led by The Mothers of East L.A. with funding from MWD and Los Angeles Department of Water & Power, to retrofit older water-wasting toilets.

GETTY IMAGES

public-interest organizations created the California Urban Water Conservation Council (CUWCC) in 1991. The council has since identified 14 "Best Management Practices," including toilet retrofits, horizontal-axis washing machines, metering, and public education, to help ensure reliability by reducing demand.

The San Francisco Public Utilities Commission has implemented a number of the Council's recommendations and is providing water-conservation incentives to its residential, commercial, and large-landscape customers; more generally, the SFPUC is engaging in public outreach. The Commission estimates that water-conservation measures will help reduce its retail demand in 2020 by over 30,000 acre-feet.

Other urban water agencies, including some members of the Bay Area Water Supply and Conservation Agency, are either not members of the CUWCC or have only begun to implement its recommendations. This suggests that considerable untapped possibilities remain for water conservation in the Bay Area and likely in other parts of the state as well.

RECYCLED MUNICIPAL WATER

Water recycling, which involves treating municipal wastewater sufficiently to protect public health and then making it available to customers—normally, for non-potable uses—has been used in California since the 1800s. But it has become a significant supplemental water source only in the past few decades. Currently, California's urban areas recycle about 500,000 acre-feet of wastewater annually, and the statewide potential is estimated to be some 1.5 million acre-feet per year statewide by 2030.[10]

Public policy in California has placed a high priority on replacing freshwater with recycled water for uses such as industrial processes or irrigation. The San Diego County Water Authority, for example, currently reuses 13,000 acre-feet of recycled water, or 3 percent of total supply, each year; and by 2020 it is projected to reuse over 53,000 acre-feet per year, or 6 percent of total supply.[11] The Southern California Water Recycling Initiative, a partnership of 10 urban water agencies (including SDCWA and MWD), plans to launch 34 new projects by 2010 with a total potential yield of 451,500 acre-feet per year of additional recycled water.

The San Francisco Bay Area is beginning to catch up with the southern part of the state. The Contra Costa Water District currently recycles some 10,000 acre-feet per year—about 8 percent of its total use. The SFPUC is currently developing a cost-effective system to deliver recycled water to parks, open spaces, golf courses, street medians and commercial buildings, as well as to other customers for non-drinking purposes. Once it is implemented in 2006, San Francisco's Recycled Water Program should be producing almost 17,000 acre-feet per year[12] or 6 percent of total supplies. Meanwhile, the Bay Area water and wastewater agencies, assisted by state and federal agencies, have formed a partnership—the Bay Area Regional Water Recycling Program—and have collectively identified a recycled water market of at least 125,000 acre-feet per year in the Bay Area.

DESALINATION

New technologies have created increased optimism that desalination, a water-treatment process that removes salt from brackish water and seawater, might play a significant role in assuring future water supplies. Since the mid-1960s, urban water agencies throughout the state had found desalination to be infeasible because of its associated high energy and environmental costs. Over the past decade, however, improvements in technology combined with the increased cost of conventional supplies have made desalination competitive, in some cases, with importing water or recycling water.[13]

In a joint effort, the four largest Bay Area urban agencies (SFPUC, East Bay Municipal Utility District, Contra Costa Water District, and Santa Clara Water District) are currently exploring the development of regional desalination facilities. Through this Bay Area Regional Desalination Project, it is estimated that almost 135,000 acre-feet per year could be available for potable use by 2020 at an economically viable cost of $377–429 million (2002 dollars).

Bay Area water interconnections

The Bay Area's largest water agencies developed independently, with separate infrastructure and their own sources of supply. In many cases, these agencies have pipelines that cross but do not interconnect, making it difficult for them to help each other in times of need. In 2000, the Association of Bay Area Governments and the CALFED Bay-Delta program (a collaboration of state and federal agencies) acted to address this oversight. The two entities established a task force of local urban water agencies to help coordinate and connect these independent systems and to encourage their mutual pursuit of conservation and water transfers. As the many water agencies are finally starting to work together, some interconnections have already been completed.

CHAPTER 4

California power summary

Californians, whose economic prosperity and quality of life are largely dependent on a reliable electric-power system, have become increasingly aware of the need for energy resources that are both efficient and environmentally friendly. The shortages and price spikes of 2000–2001 also brought home the value of locally controlled generation, renewable energy, and conservation. This chapter provides an overview of California's power system, including the electricity operations of Hetch Hetchy Water and Power and the Turlock and Modesto Irrigation Districts.

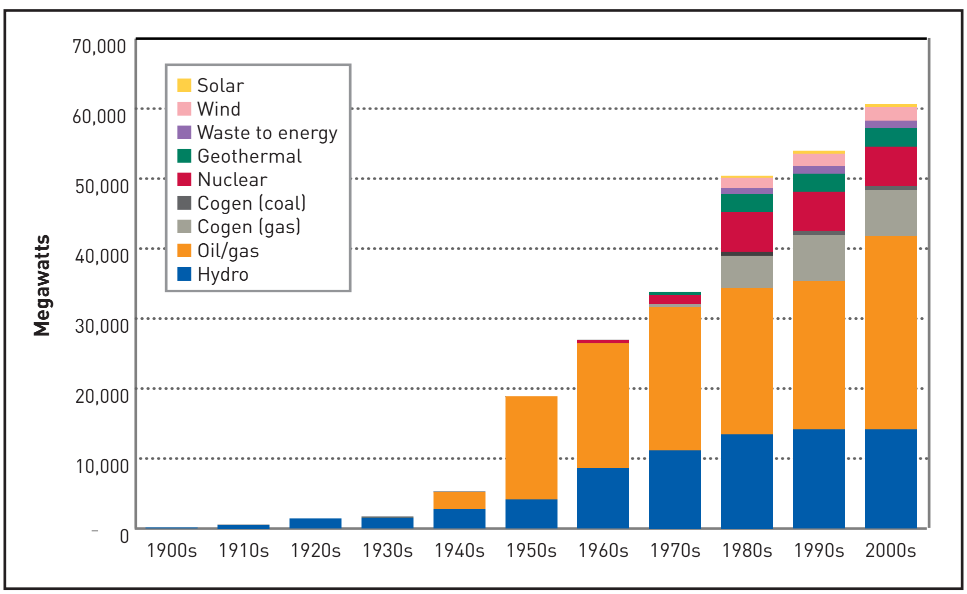
Overall system

California's electric-power system is comprised of an intricate grid of power plants, transmission lines, and distribution lines that were developed over the past century by utilities in order to link sources of electrical energy (both in-state and out-of-state) to end users. California's grid is extensively interconnected with a much larger regional grid that encompasses parts of all 14 Western U.S. states, the Canadian province of British Columbia, and the Mexican state of Baja California. The routine exchange of energy with producers throughout western North America ensures a reliable supply of electricity for California's expanding population and growing business sector.

Figure 4-1 shows how the state's portfolio of generating resources has evolved since the early days of electrification. During the early and middle part of the 20th century, rivers were the main source of Californians' electricity. But in the last few decades, hydroelectric development has dropped significantly: few cost-

FIGURE 4-1

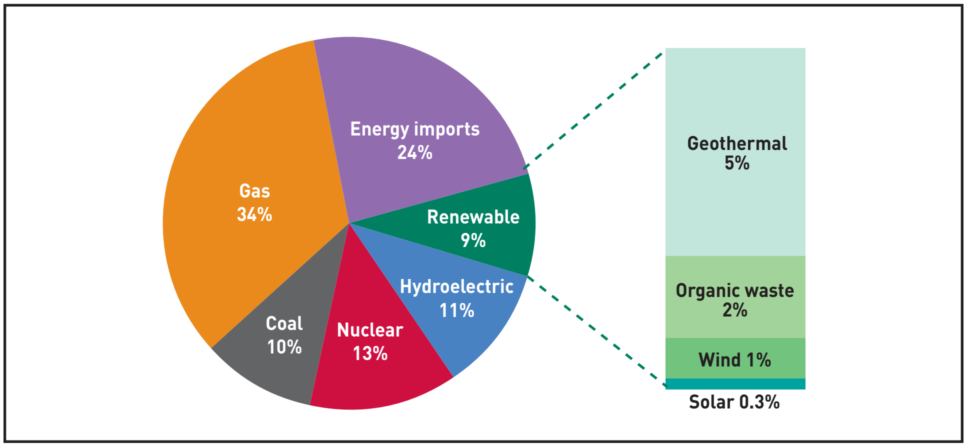
Cumulative generating capacity in California by decade and energy



Hydrogen provided most of California's energy supply in the early days of electrifiction. More recently, fossil-fired plants and nuclear energy have met most of the state's ever-growing demand for electricity, as the number of cost-effective hydroelectric sites has dwindled and public opposition to new dams has mounted.

Source: California Energy Commission

FIGURE 4-2
California electricity sources, 2002



California relies on a diverse portfolio of resources to meet its energy needs. Renewable energy sources such as geothermal, wind and solar power will increase as the state's investor-owned utilities comply with a new law that requires them to obtain 20 percent of their supply from renewable sources by 2017. Source: California Energy Commission

effective hydroelectric sites remain, while public opposition to new dams has grown. Fossil-fuel-fired plants have met much of the state's ever-growing demand since the 1950s, with newly built fossil-fuel facilities now using natural gas. Several large nuclear reactors came on line in the 1980s, but none have been developed (or proposed) since then. In the last quarter-century, over 5000 megawatts of renewable generation have been added to the state's resource mix.

Today, California's electricity portfolio includes a combination of natural gas, coal, hydropower, nuclear, and renewable-energy sources, as shown in Figure 4-2. Annual mixes vary dramatically from year to year, depending on factors such as precipitation and natural-gas prices. A significant recent development, which will shape the evolution of the state's power supply, was the Legislature's adoption of a renewable portfolio standard (RPS). Passed in 2002, SB1078 (Sher) requires that California's investor-owned utilities, including Pacific Gas and Electric Company, purchase 20 percent of their electricity from renewable sources by 2017. Although municipal utilities, including irrigation districts, are exempt from the RPS, some have undertaken voluntary efforts to increase their reliance on renewable energy.

Imported electricity accounts for a significant part of the resources for meeting the state's electricity needs. Hydropower from the Northwest and coal-fired generation in the Southwest provide much of California's imported energy, but interconnection with other Western states means that power from all types of sources can flow here from throughout the region. Ongoing construction of new gas-fired plants in the Mexican state of Baja California may add a new source of imports. In 2002, California imported approximately 62,859 million KWh, while power plants within the state generated approximately 209,650 million KWh.

Conservation and energy efficiency are playing an increasingly important role in balancing California's electricity supply and demand. Since the 1970s, residents have invested in upgrading buildings and equipment so that electricity may be used more sparingly, and these investments have paid off. The

California Energy Commission (CEC) estimates that since 1977 Californians have shaved 6000 MW from peak demand, the equivalent of a dozen new natural-gas power plants.[1] Meanwhile, technological innovation continues to yield new efficiency-enhancing—and relatively low-cost—technologies.

Beyond the last three decades' impressive progress, the shortages and price spikes of 2000–2002 taught Californians that they could save even more energy. About 70 percent of the significant peak-load reduction that California realized during the summer of 2001 came from conservation— behavioral changes such as darkening empty rooms, shutting off idle equipment and turning down the air conditioning.[2] The rest of the savings came from new investments in energy-efficiency measures such as replacing incandescent light bulbs with compact fluorescent lamps, discarding old air conditioners in homes and offices in favor of newer and more efficient models, installing energy-management systems, and even coating rooftops with reflective materials.

An especially important development is the installation of sophisticated new electricity meters for most of the state's large energy users. These devices will permit such customers to participate in "dynamic pricing" programs that provide incentives for them to cut power use during peak periods. Adding this demand-side flexibility means that fewer new power plants will be needed to accommodate the relatively few hours each year when energy demand is at its maximum level. According to CEC forecasts of the resources required to meet California's future energy needs, dynamic pricing could pare more than 2500 MW from system peak demand, avoiding the need for at least five new natural-gas powerplants.[3]

Although these advances are slowing the growth in demand for electricity, California still needs to develop new generating capacity to maintain adequate energy supplies. Power-plant construction in the state has recently followed a boom-bust pattern, partly in response to changing policies toward cost recovery and industry structure. The Legislature's enactment in 1996 of a law that radically restructured the electricity industry, AB1890, ended a 10-year lull in new construction and launched a rush to build new power plants. Although the new plants were not finished fast enough to prevent shortages and price spikes in 2000–2001, their steady arrival since then has brought supply and demand back into balance. Since 2001 over 8000 MW of new generating capacity has come on line in California, and the state currently enjoys an energy surplus. But the rate of new construction has once again slowed, and shortages may return in just a few years if the pace of development does not pick up.

Electricity units

Watt (W): Basic measurement for the rate of power output or use

Watt-hour(Wh): Basic measurement for energy output or use. For example, a 100-W light bulb that is on for 10 hours has used 1000 Wh of energy.

Kilowatt (KW)—1000 watts: Kilowatt-hours (KWh) is the usual basic unit on consumers' electric bills.

Megawatt (MW)—1,000,000 watts: is usually the unit used to measure power-plant capacity. Yearly output is sometimes measured in megawatt-hours.

The U.S. average residential monthly energy usage in 2002, according to the U.S. Department of Energy (DOE), was 907 KWh.

Net energy production in the United States in 2002, according to the DOE, was 3,858,452 million KWh.

Net energy production in California in 2002, according to the CEC, was 272,509 million KWh.

The current construction slowdown is happening mainly because private-sector power-plant developers cannot get financing for new projects. Skittish lenders are withholding funds, citing their uncertainty about the industry's future structure and regulatory environment as California legislators and regulators develop new policies to reconfigure the industry once again.

Policymakers have gone back to the drawing board because AB1890 is widely perceived as a failure, even though the bill's passage did help stimulate the recent wave of new construction. In particular, flaws in AB1890's market redesign have been blamed for creating conditions that allowed the Enron Corp. and other power marketers to exploit the tight market conditions of 2000-01, thereby driving electricity prices to astronomical levels and imperiling the financial health of the state's three big investor-owned utilities. Consequently, policymakers are revisiting critical questions, including who will be responsible for building new projects (utilities or independent merchant generators?) and how to assure developers' recovery of construction costs even as they are held accountable for unreasonable delays and excessive expenses.

California's many municipal utilities have not experienced the credit crunch, however, and have continued to build new plants even as private-sector construction has lagged. Although they must secure approval from state environmental regulators for new projects larger than 50 MW, municipal utilities such as the Turlock and Modesto Irrigation Districts are mostly unaffected by the regulatory changes now being considered. These changes will mainly affect investor-owned utilities, such as Pacific Gas and Electric Company, which serve over 80 percent of California's electricity demand.

Hydropower and California's rivers

Almost all of California's major river systems, including the Tuolumne, have been developed not only to supply water but also to produce hydropower. Over the past 20 years the proportion of California's energy provided by in-state hydroelectric facilities has varied from 9 percent to nearly 30 percent, depending on precipitation, the timing of spring snowmelt, and other factors. Hydropower produces no emissions of harmful air pollutants or global-warming gases, and production costs at existing facilities are typically low. Some hydroelectric plants also play an important role in maintaining a robust electric system by varying their energy output rapidly, in response to grid operators' signals, to assure the grid's stability. It should be noted, however, that California's new gas-fired plants share this operating flexibility, thereby reducing the need for hydroelectric facilities.

Although hydropower is clean, it is not always green: hydropower facilities throughout California have had significant adverse impacts on aquatic ecosystems. Dams block fishes' access to spawning and rearing habitat (causing declines in many native fish populations), while diversions of water from natural riverbeds cause environmental degradation. Sudden changes in river flows can occur downstream of hydropower facilities when production is ramped up (i.e., to provide power during peak demand), further harming streamside and river ecosystems.[4] A 1996 report by the University of California, Davis—the most ambitious compilation of research on the Sierra Nevada to date—deemed rivers and riparian ecosystems the "most endangered" habitats in the Sierra, and it identified dams and other hydropower facilities as their number-one threat.[5]

In many cases federal law provides an avenue to address these problems. The

Federal Energy Regulatory Commission (FERC) regulates private, state and local hydropower projects that are larger than 5 MW. In California there are 119 FERC-licensed dams, with 11,930 MW of generating capacity (85 percent of California's total hydropower portfolio). Environmentally important operating parameters, such as provisions for fish passage and required flows in bypassed reaches, are specified in 30- to 50-year licenses granted by FERC.

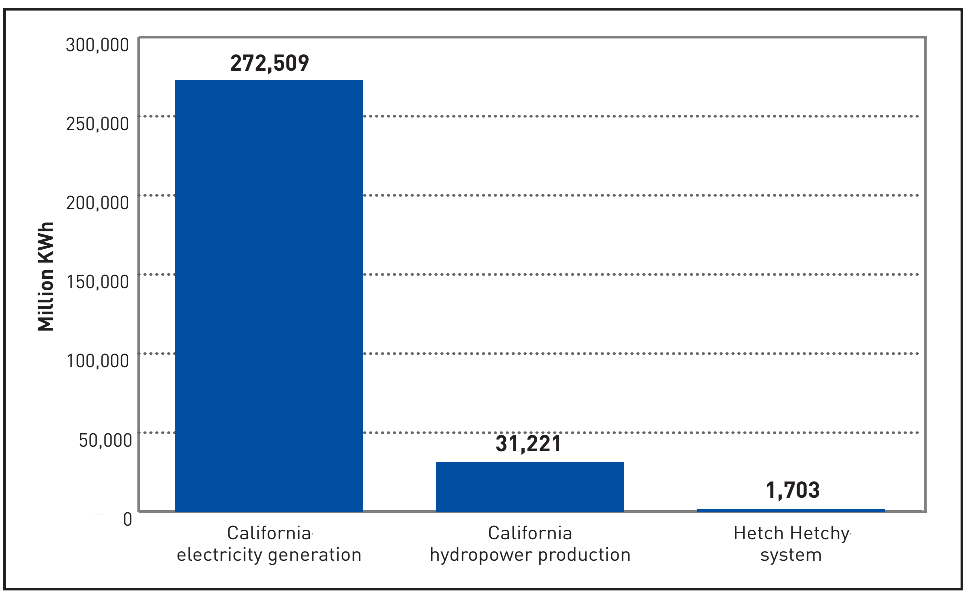
Most of California's FERC-licensed plants came on-line more than 30 years ago, before the emergence of the modern environmental movement and the passage of today's environmental laws. As these projects' FERC licenses come up for renewal over the next two decades, Californians will have the opportunity not only to bring them into compliance with current regulations but to weigh their electricity benefits against their environmental costs in light of contemporary public policies and community values.

However, the Federal Power Act (section 29) stipulates that "nothing herein shall be held or constructed to modify or appeal any of the provisions of the Act of Congress approved December 19, 1913 [the Raker Act]," granting certain rights of way to the City and County of San Francisco in the State of California. Consequently, FERC does not oversee San Francisco's hydroelectric plants on the Tuolumne River.

Hetch Hetchy hydropower and its users

San Francisco operates three hydroelectric plants—the Kirkwood, Moccasin and Holm powerhouses—on the Tuolumne River (see Chapter 5). While they provide a significant amount of energy to the City of San Francisco and to Central Valley communities, these facilities account for only a tiny fraction of the electricity produced statewide. As illustrated in Figure 4-3, in 2002

FIGURE 4-3
Hetch Hetchy hydropower in perspective, 2002



The SFPUC's hydroelectric plants play a minor role in meeting California's energy needs. In 2002 they provided just 5.5 percent of statewide hydropower production and 0.6 percent of the state's overall electricity supply.

Source: California Energy Commission and United States Department of Energy, Energy Information Administration the three plants provided 0.6 percent of California's electricity supply and represented 5.5 percent of statewide hydropower production. Also, only the Moccasin and Kirkwood plants actually generate power using water stored behind O'Shaughnessy Dam.

Chapter 9 presents an analysis of how restoring Hetch Hetchy Valley would affect hydropower generation on the Tuolumne River.

Meanwhile, although the Hetch Hetchy Reservoir accounts for only a small part of California's overall electricity supply, it is an important and valuable resource to the people who use it. The remainder of this section discusses the role of Hetch Hetchy power in meeting the needs of electricity customers in San Francisco and in those parts of the Central Valley served by the Turlock and Modesto Irrigation Districts.

SAN FRANCISCO

Most homes and businesses located in San Francisco receive their electricity from Pacific Gas and Electric Company (PG&E). However, the electrical energy delivered to the airport, the Port of San Francisco and San Francisco General Hospital, and other City-owned facilities, are provided by the Hetch Hetchy Water and Power system; PG&E provides the transmission and distribution services that deliver power to these customers.

As a practical matter, electrons originating from San Francisco's Tuolumne River hydroelectric generators are commingled with those from the diverse array of resources that feed into the Western grid. However, for cost accounting and other purposes, power-market participants keep track of what they "pour into" the grid and what they draw out of it. Thus, PG&E delivers a mix of Hetch Hetchy and purchased power to City facilities while serving its own retail customers in San Francisco with its own blend of purchased and self-generated energy.

Total electricity consumption in the City of San Francisco was 5,374 million KWh in 2002 and has been slowly rising in recent years (except for a dip during the energy shortages of 2000–2001).[6] According to data reported annually by the San Francisco Public Utilities Commission (SFPUC) to state agencies, Hetch Hetchy energy supplied to public facilities has been approximately 900 million KWh per year in recent years.[7] Although average generation from the SFPUC's Tuolumne powerhouses significantly exceeds the City's public-sector needs—as discussed in Chapter 5, the balance is sold to the Turlock Irrigation District, the Modesto Irrigation District, and other utilities and power marketers—it is less than a third of overall consumption in San Francisco. Even if all Hetch Hetchy energy were made available for all users in the City, considerable additional resources would be required.

San Francisco has developed an Electricity Resource Plan that sets ambitious environmental, economic and equity goals for meeting the City's electricity needs through 2012. In the short term, closing the highly polluting Hunters Point and Potrero plants will yield significant advances on all of these fronts (see *Clearing the Air in San Francisco,* page 28). For the longer term, the Plan calls for maximizing energy efficiency in City buildings and investing in renewable energy technologies such as wind and solar. In 2002, San Francisco joined other cities in setting the 2012 goal of greenhouse-gas emissions that are 20 percent below the 1990 levels; to meet this goal will require significantly increasing the share of renewable energy in the City's portfolio.

Clearing the air in San Francisco

Air pollution from aging power plants in low-income, predominantly non-white communities is a major environmental-justice issue in San Francisco. PG&E's Hunters Point power plant and the Potrero Unit 3 (operated by the Mirant Corporation) are among the oldest and dirtiest plants in the state; Hunters Point is the City's most significant stationary source of air pollution.

Plans to close these plants have been developed, but they are currently on hold. Standing in the way is the California Independent System Operator (CAISO), which controls the state's electricity grid and is responsible for assuring reliable service. The delay derives not from any shortage of replacement power but from a transmission bottleneck that limits the flow of power into San Francisco. Because almost all of the City's electricity supply is imported via a few transmission lines that run up the peninsula, the CAISO requires a City-based backup source of power should the peninsula suffer a transmission outage. Therefore the CAISO will not allow Hunters Point and Potrero to close until new transmission lines are built or enough new local generation is added to guarantee reliable service in the City.

In any case, efforts to restore Hetch Hetchy Valley would not be adversely affected by the closure of Hunters Point and Potrero. As discussed in Chapter 9, there are several options for developing new resources to replace the hydropower that would be lost, and these supplies would most likely be imported into San Francisco, just as Hetch Hetchy energy is now. New generation or conservation resources developed locally to enable the closing of Hunters Point and Potrero might even hasten the valley's restoration.

TURLOCK IRRIGATION DISTRICT

Organized in 1887, the Turlock Irrigation District (TID) is the oldest irrigation district in California and was the first in the state to sell electricity on a retail basis.[8] TID provides water to 5,800 growers in Stanislaus and Merced Counties and electricity service to over 77,500 retail accounts. In addition, TID currently sells surplus energy at a profit when opportunities arise: from 1998 to 2002, the district's annual wholesale power sales ranged from 148 to 1,002 million KWh. Major objectives for TID's power supply operations are minimizing power procurement costs, maximizing the extent of local decision-making, and maintaining independence from outside control.

While most of TID's energy needs are met with purchased power, the district also owns two 49-MW natural-gas-fired power plants and it has financial interests in hydroelectric plants whose capacity totals 152 MW. With a two-thirds ownership share in the Don Pedro Dam, TID takes the lead in managing that facility's hydropower operations, as well as its flood-control, recreation, and water-supply operations. A new 250-MW gas-fired plant, expected to enter service in 2006, is currently under construction in the City of Turlock. TID also has holdings in transmission capacity and generation resources elsewhere in California and the Northwest through its membership in public-power consortiums and long-term power-purchase contracts.

Hetch Hetchy energy has generally accounted for about 10-15 percent of TID's supply. Until recently, TID bought power from San Francisco under a 1987 contract that provided for purchases of firm power, as well as the surplus, to which the Raker Act entitles the District. San Francisco terminated the contract early in February 2004, but

TID continues to dispute whether the termination was valid.

MODESTO IRRIGATION DISTRICT

The Modesto Irrigation District (MID) provides electricity to over 100,000 retail accounts in rapidly growing parts of Stanislaus County. From 1998 to 2002, MID also sold between 385 and 1,047 Million KWh annually to wholesale customers. MID seeks to maintain a balanced portfolio of energy sources, including hydropower, natural gas, geothermal energy and coal. In 2002, nearly 90 percent of the energy that MID distributed to its customers was purchased, mostly through long-term contracts.

MID's principal sources of purchased power are the Hetch Hetchy system and the M-S-R Public Power Agency, through which it owns a portion of the energy produced by the San Juan coal-fired plant in New Mexico. MID also buys energy from the federal Central Valley Project and others, under various agreements, and it purchases a limited amount of energy on the short-term "spot market." MID's own generating resources include the 49-MW Woodland Avenue and 112-MW McClure natural-gas-fired plants and an approximately one-third interest in the Don Pedro Dam's hydroelectric generation. In 2002, purchases of Hetch Hetchy energy accounted for about one-fifth of MID's supply.

According to its 2002 Annual Report, MID intends to reduce its dependence on the state grid through more investments in local generation sources. Current projects include additions and upgrades to MID's existing facilities, and plans to build a new 90-MW gas-fired plant. MID is also exploring options to expand its resource base by acquiring additional interests in hydroelectric and coal facilities, entering new long-term power purchase contracts, and investing in conservation and renewable energy.

MID and its customers recognize the value of investing in energy efficiency. MID already operates several programs, including an air-conditioner cycling project, to shave summer peak loads. In a 2002 survey of 800 MID residential and commercial customers, 75 percent ranked energy conservation as "important" or "very important."[9]

Moving water

In the present study (on which this report is based), a number of alternatives to storing water in Hetch Hetchy Reservoir are being considered that may require transporting water to another storage site. But water is heavy. Excepting cases where it can be moved via gravity, significant energy is required to move and pump water. California's rugged landscape, moreover, makes the transport of water from sources to population centers especially energy-intensive, using an average of 1,955 KWh per acre-foot—almost twice the average power needed for this purpose in most other states.[10]

Pumping is the single largest cost category for the State Water Project, which transports water from the Sacramento-San Joaquin Delta more than 300 miles south over the Tehachapi Mountains to the L.A. Basin.[11] Approximately 3,200 KWh per acre-foot are required to deliver water from the Edmonston pumping plant to the Devil Canyon Power Plant Afterbay, a net lift of 1,924 feet.

CHAPTER 5
The Tuolumne River and Bay Area water system

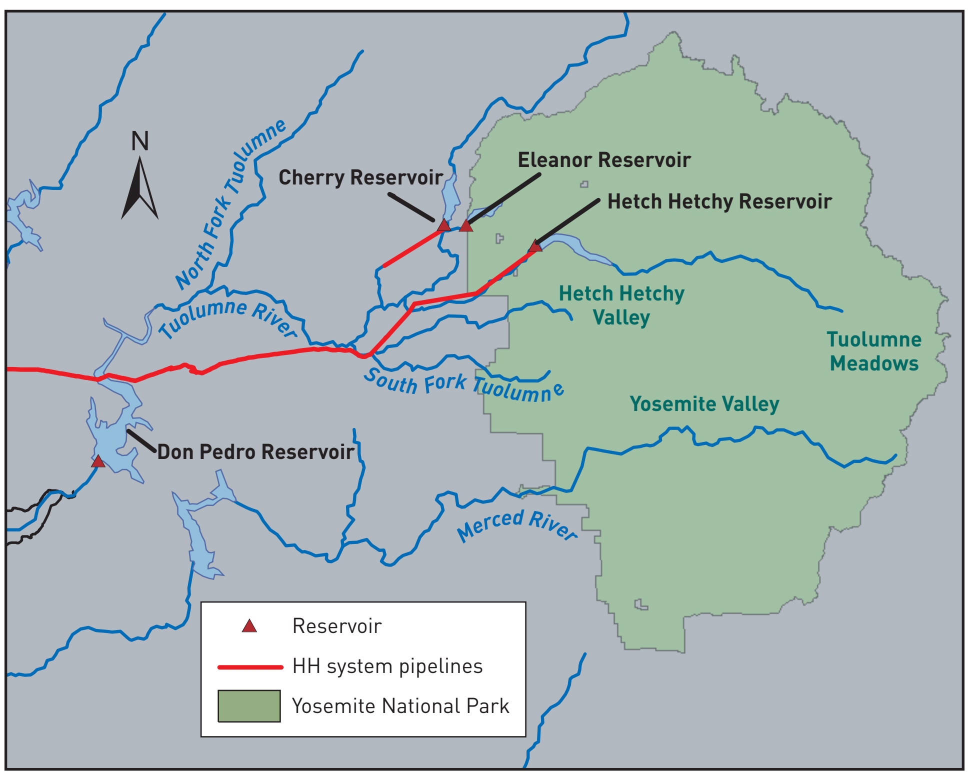
The Tuolumne River has been extensively developed so that its water and hydropower may be delivered to multiple users. In addition to meeting these demands, the Tuolumne River watershed supports a wide variety of wildlife and provides excellent recreational opportunities. This chapter provides an overview of the Tuolumne River watershed, including descriptions of its annual hydrology, related water rights, and dams. Also discussed are water-supply operations, hydropower operations, and recreation and ecosystem protections.

Watershed overview

The Tuolumne River is one of the largest rivers in California's Sierra Nevada mountain range, with headwaters lying above the 10,000-foot level in Yosemite National Park. The main river begins in Tuolumne Meadows at the confluence of streams descending from the slopes of Mt. Lyell (13,100 feet) and Mt. Dana (13,155 feet). Tuolumne Meadows (8,600 feet), easily accessed from Highway 120, is a popular high-country destination for summer visitors. From there the river descends through the steep Yosemite wilderness, including the Tuolumne's own "Grand Canyon," before its flow is impounded by the O'Shaughnessy Dam in Hetch Hetchy Valley (3,500 feet).

In addition to its tributaries within Yosemite National Park, several other streams add to the Tuolumne's flows at lower elevations in the Sierra Nevada. Just below the park, Cherry Creek

FIGURE 5-1
The Upper Tuolumne River system



enters the river. Further downstream, the Tuolumne's South and North Forks, as well as the Clavey River, join the main stem (Figure 5-1). Like all other rivers that descend the Sierra's western slope, the Tuolumne is a "hard-working" river, largely controlled by a plumbing network that provides water to farms and cities while generating valuable electricity.

HYDROLOGY

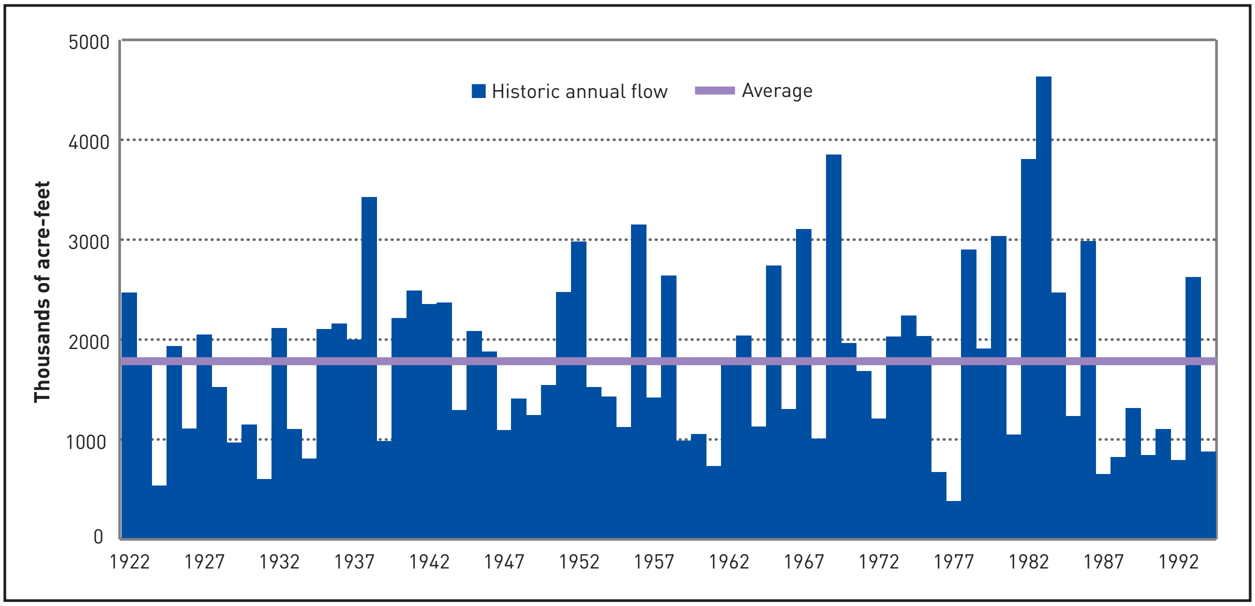
With an average annual flow of about 1.8 million acre-feet, the Tuolumne is the largest river flowing into California's San Joaquin Valley. About 60 percent of the river's flow occurs between April and June, when warm weather melts the Sierra snowpack. As shown in Figure 5-2, the Tuolumne's flows, like those of most California rivers, vary widely with annual precipitation. In about one out of every four years, the annual flow is less than 1.1 million acre-feet.

For agencies responsible for delivering water to urban or agricultural customers, drought periods (i.e., successive dry years) are of great concern. Three droughts in particular during the period of hydrologic record (1922–1994) have caused water planners in California to pay special attention. Depending on a district's location in the state and its water-supply options, any one of the three might be considered the most severe. The bone-dry two-year drought in 1976–1977 hit some districts—especially those with limited alternatives—the hardest. The Marin Municipal Water District, for example, was forced in 1977 to build an emergency pipeline across the Richmond-San Rafael Bridge. For most of the California, which relies heavily on supplies from the Sacramento Valley, a repeat of the seven-year drought from 1928-1934 would cause the most difficulty. For the Bay Area communities that are served by the Tuolumne River, however, a repeat of the more recent drought from 1987–1992 would be most severe.[1]

WATER RIGHTS

Under state law, the Turlock and Modesto Irrigation Districts control far more of the Tuolumne River than does the San

FIGURE 5-2
Historic Tuolumne River flows (1922–1994)



The Tuolumne's flows, like those of most California rivers, vary widely with annual precipitation. Source: California Department of Water Resources

Francisco Public Utilities Commission (SFPUC). These "senior" water-rights holders are entitled to the river's base flow, with water accruing to the "junior" SFPUC only during periods of high flow. The exact distribution is determined daily by a calculated estimate of what the flow would be at La Grange (located just below Don Pedro Reservoir), absent any dams on the river. Most of the year, all of the river's flows below 2,416 cubic feet per second (cfs) belong to the two Districts. Unless the flow is higher than this threshold, San Francisco and the rest of the Bay Area get absolutely no water. Over the 60-day period from mid-April to mid-June, typically the period of highest river flow due to melting snow, that threshold is raised to 4,066 cfs.

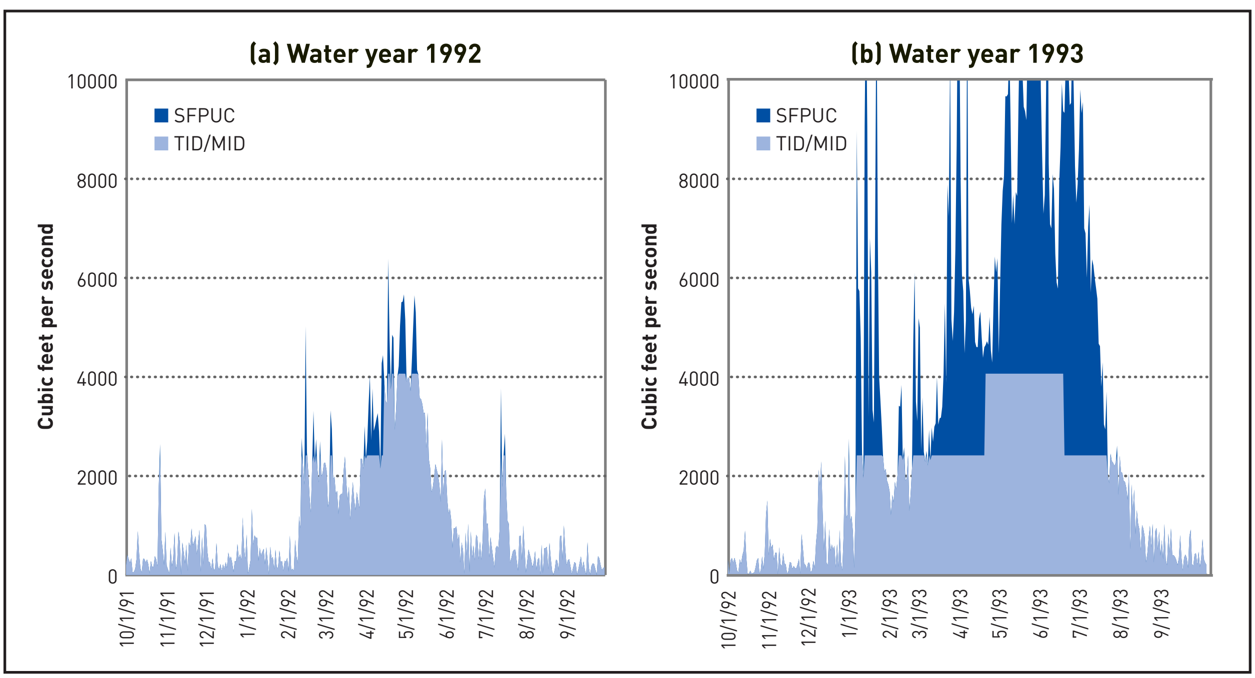
Given its limited water rights, therefore, in many years very little of the Tuolumne's flow belongs to the SFPUC. In 1977, the driest year on record, only 3,000 acre-feet accrued to the City. With very limited alternative sources, it is more dependent on storage than most other urban districts.

The rate of the flow in streams and rivers is typically measured in **cubic feet per second (cfs)**. One cubic foot is about 7.5 gallons; one cfs is equivalent to 724 acre-feet per year.

Figures 5-3a and b show two examples of how water rights are divided between the Turlock and Modesto Irrigation Districts and the SFPUC, in accordance with the daily criteria specified by their respective water rights. 1992 was not only a dry year, it marked the sixth-straight year of a drought. Less than 25 percent of San Francisco's delivery objective, only 68,000 acre-feet (mostly in April) accrued to the City that year. Because storage in its dams was low due to the extended drought, the City and other retail agencies asked customers to

FIGURE 5-3

Tuolumne River water rights distribution



For Bay Area water users, the extremes of the Tuolumne's natural hydrology are exacerbated by the SFPUC's "junior" water rights. 1992 was not only a dry year, it marked the sixth straight year of drought. Fortunately, in 1993, heavy rains and snowfall returned to the Tuolumne River watershed.

Source: California Department of Water Resources

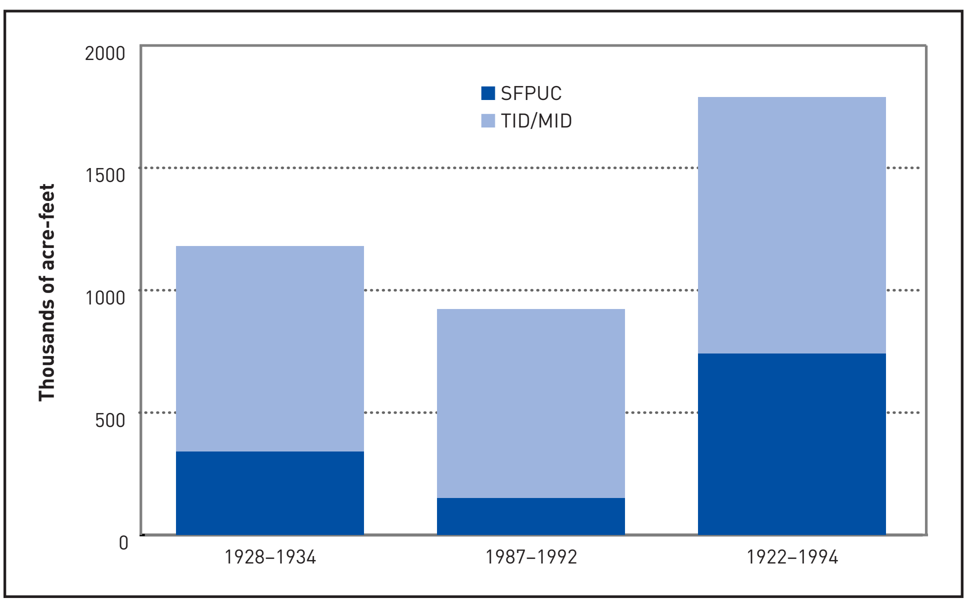
The hydrologic **water year** is the 12-month period lasting from October to September. For instance, the year ending September 30, 2002 is referred to as the "2002 water year."

conserve. The City also bought additional supplies from the California's emergency drought water bank. Fortunately, 1992 was the last year of the drought. In 1993, rain and snow returned to the Sierra Nevada, allowing full water deliveries and replenishing diminished surface storage in the Tuolumne River watershed and the Bay Area.

Figure 5-4 shows how the annual flow of the Tuolumne River is divided between the San Francisco Public Utilities Commission and the Turlock and Modesto Irrigation Districts on average (1922–1994) and during the droughts of 1928–1934 and 1987–1992. The total volumes were similar during the two droughts, though the earlier period was slightly wetter. Between 1987 and 1992, the SFPUC's average annual water-rights accrual was 151,000 acre-feet, about half of its current water-delivery objective. Assuring enough supply under existing water rights to allow the Bay Area to make it through such a drought with sufficient water both for homes and businesses is one of the SFPUC's biggest challenges.

Water agencies throughout the West normally rely on historic hydrologic records for their planning studies. But many planners are beginning to grapple with potential changes, both in the magnitudes and timing of future precipitation that may occur because of global warming. As events unfold, particular users may be better or worse off; under the water-rights criteria regarding the Tuolumne River, peak snowmelt occurring earlier could actually increase the SFPUC's supplies at certain times. If the peak snowmelt from mid-April through mid-May in 1992 (Figure 5-3a) had occurred a month earlier, for example, the SFPUC would have been entitled to all flows above

FIGURE 5-4
Historic Tuolumne River water rights distribution average and drought periods



Between 1987 and 1992, the SFPUC's average annual water-rights accrual was 151,000 acre-feet, about half of its current water-delivery objective.

TABLE 5-1
Principle Tuolumne River and SFPUC reservoirs

Region reservoir	Storage capacity (thousand acre-feet)
Bay Area	
Pilarcitos	3
San Andreas	19
San Antonio	51
Crystal Springs	69
Calaveras	97
Upper Tuolumne	
Eleanor	27
Cherry	273
Hetch Hetchy	360
Lower Tuolumne	
Don Pedro[2] (SF Water Bank)	634
Don Pedro (MID/TID Portion)	1395
SFPUC Total	**1533**

2416 cfs (as opposed to only those flows over 4066 cfs). Under these hypothetical circumstances, the SFPUC would have received more water, while the Turlock and Modesto Irrigation Districts received less. In any case, the prospect of global warming has added one more factor that water agencies must take into account as they develop plans to ensure the reliability of their systems.

DAMS

Like all major rivers in the Sierra Nevada, the Tuolumne River watershed is dammed in several places, principally to provide reliable water supplies for California's farms and cities. Table 5-1 lists the reservoirs on the Tuolumne, along with their storage capacities. Hetch Hetchy, with 360,000 acre-feet of storage capacity, is the largest in the upper watershed. The SFPUC owns and operates two other "up-country" reservoirs: Lake Eleanor (27,000 acre-feet) also lies within Yosemite National Park, while Cherry Valley Reservoir (273,000 acre-feet) lies just outside (see Figure 5-5).

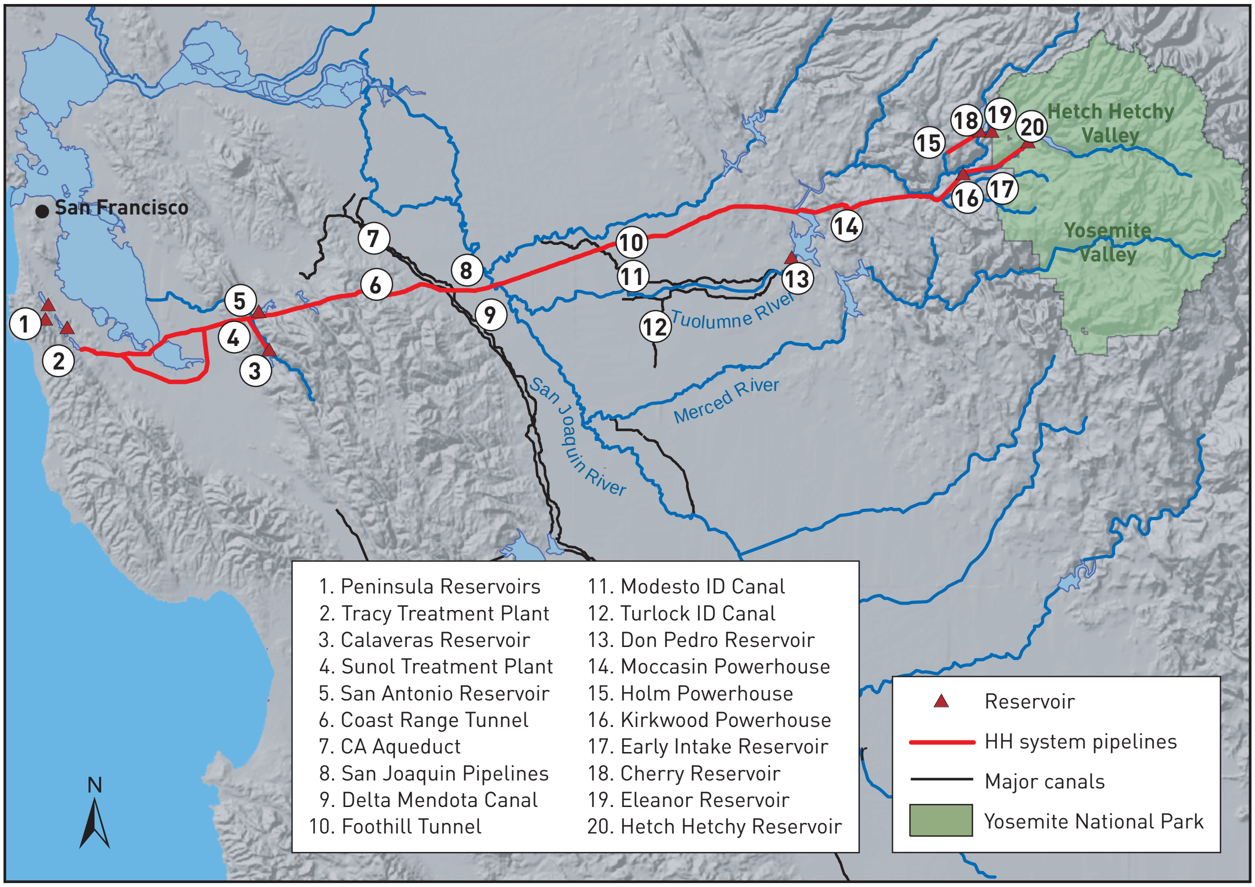
The largest reservoir on the Tuolumne River is Don Pedro, which holds just over 2 million acre-feet of water. Most of Don Pedro's storage capacity is dedicated to meeting summertime and dry-year needs of the Turlock and Modesto Irrigation Districts. The SFPUC does not divert water directly from Don Pedro, but owns the right to store up to 740,000 acre-feet in the reservoir (more than twice the total volume of Hetch Hetchy Reservoir).

San Francisco therefore uses its storage in Don Pedro as a water "bank." When Tuolumne River flows are low (and by law belong to the Turlock and Modesto Irrigation Districts), the SFPUC is still able to divert river flows upstream by using its bank. In accordance with its agreement with Turlock and Modesto, it simply gives some of that water to the Districts as it impounds the upstream flow in Hetch Hetchy Reservoir or diverts it to the Bay Area.

Water storage in Don Pedro Reservoir is also managed to prevent the Tuolumne from flooding Modesto and surrounding areas. Consequently, neither San Francisco nor the irrigation districts are allowed to fill their portions of the reservoir until the end of the spring snowmelt. Despite these precautions, however, Don Pedro overflowed during the New Year's flood of 1997, causing severe damage downstream. As on many rivers, in California and elsewhere, efficient operation of a reservoir involves striking a delicate balance between two conflicting goals: filling the reservoir to ensure a plentiful water supply and keeping its storage low to prevent floods. On the Tuolumne, the most effective long-term control solution is likely to involve expansion of the tightly-constrained river channel below Don Pedro Reservoir.

The SFPUC owns several water-storage facilities in the Bay Area as

FIGURE 5-5
Overview of SFPUC water system and other Tuolumne River facilities



Hetch Hetchy Reservoir is part of an extensive system that includes several reservoirs, water treatment plants, hydropower facilities and a 160-mile series of pipelines and tunnels that carries Tuolumne River water from the Sierra Nevada to the Bay Area. Hetch Hetchy Reservoir holds less than 25% of the system's total storage capacity.

well, including the San Andreas, Crystal Springs, and Pilarcitos Reservoirs in the Peninsula region, and Calaveras and San Antonio Reservoirs in the hills above Fremont near the Sunol Valley. The Division of Safety of Dams within California's Department of Water Resources has declared Calaveras—at 97,000 acre-feet, the largest of the SFPUC's local reservoirs—to be unsafe, and presently allows it to be kept no more than one-third full.

Water-supply operations

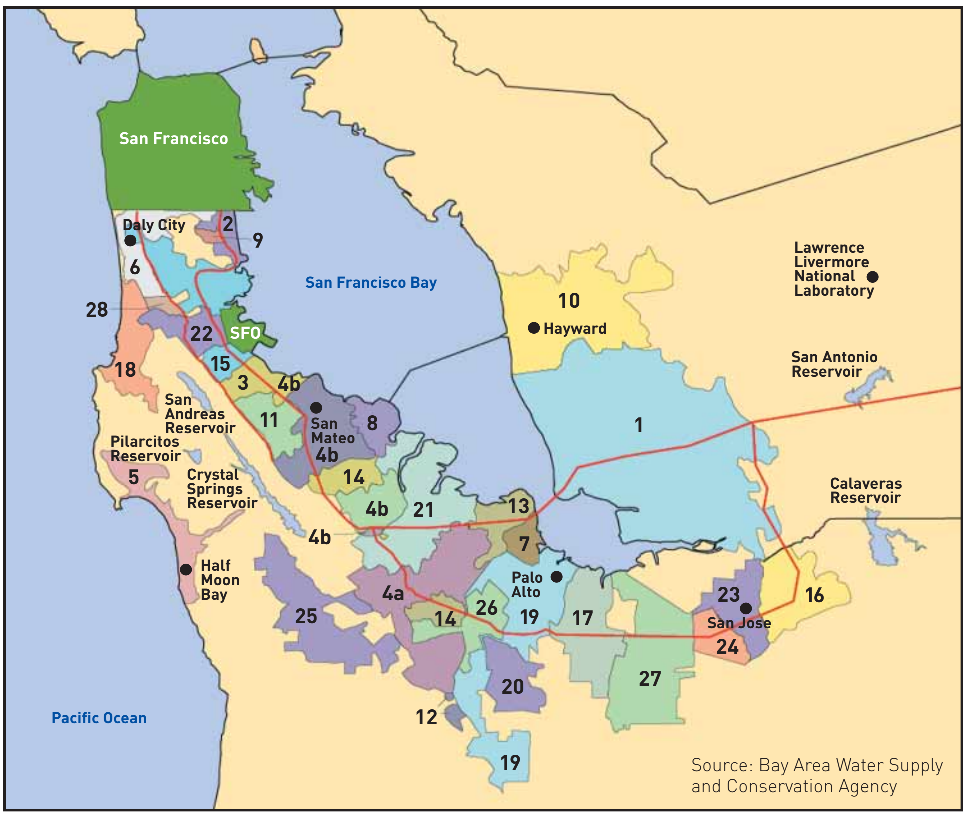
The Turlock and Modesto Irrigation Districts use most of the Tuolumne River's water. Less than one-fifth of it is diverted to the San Francisco Bay Area, to be consumed by San Francisco's residents and its customers in the Bay Area Water Supply and Conservation Agency (BAWSCA) districts. BAWSCA consists of a total of 29 wholesale districts in San Mateo, Santa Clara, and Alameda Counties (see Figure 5-6). The SFPUC also diverts a small amount of water to Groveland, a community in the foothills of the Sierra on the south side of the Tuolumne River.

Because water from the river's flow is available to the City mostly in the winter and spring, stored water is released from reservoirs to meet delivery objectives during much of the year. Currently, most water consumed by San Francisco and its customers comes directly from the Hetch Hetchy Valley via releases from O'Shaughnessy Dam. A small fraction of the supply comes from watersheds in Alameda County and on the Peninsula (San Mateo and Santa Clara Counties). At times, specifically during the drought years of 1991 and 1992, San Francisco has diverted water from the Sacramento-San Joaquin Delta directly into the San Antonio Reservoir and finally into San Francisco's distribution system.

The water diverted from Hetch Hetchy typically passes through the Kirkwood and Moccasin power plants before entering the conveyance system to San Francisco. That transport occurs entirely by gravity, starting at Moccasin then continuing through the Foothill

FIGURE 5-6

Location of BAWSCA member agencies

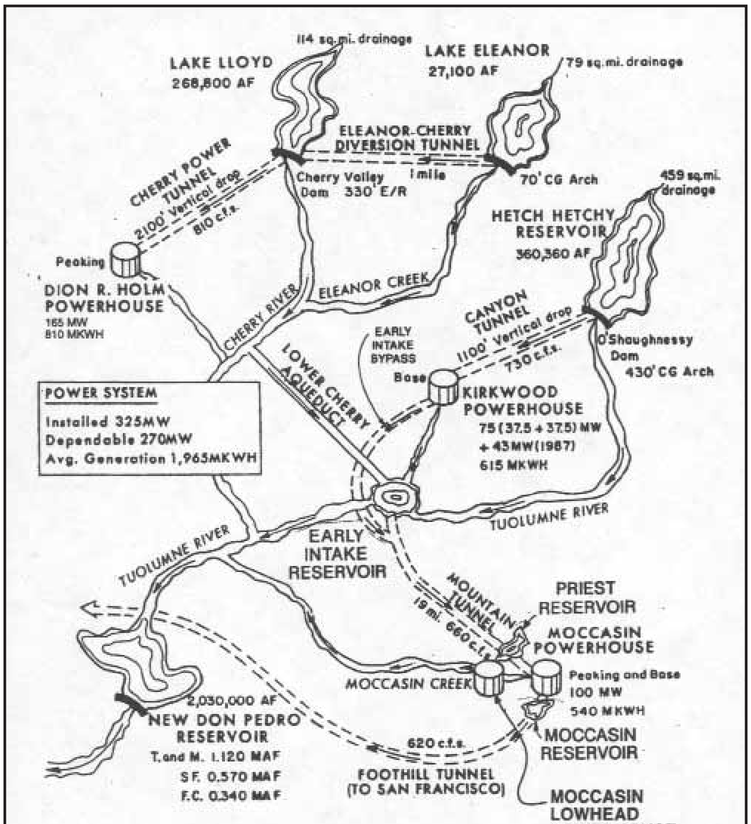


1 Alameda County Water District
2 City of Brisbane
3 City of Burlingame
4a Cal Water Service Co.-Bear Gulch
4b Cal Water Service Co.-Bayshore
5 Coastside County Water District
6 City of Daly City
7 East Palo Alto
8 Estero Municipal Improvement District
9 Guadalupe Valley Municipal Improvement District
10 City of Hayward
11 Town of Hillsborough
12 Los Trancos County Water District
13 City of Menlo Park
14 Mid-Peninsula Water District
15 City of Millbrae
16 City of Milpitas
17 City of Mountain View
18 North Coast County Water District
19 City of Palo Alto
20 Purissima Hills Water District
21 City of Redwood City
22 City of San Bruno
23 City of San Jose
24 City of Santa Clara
25 Skyline County Water District
26 Stanford University
27 City of Sunnyvale
28 Westborough Water District

Tunnel and San Joaquin pipelines into the Coast Range Tunnel. The water then crosses the Sunol Valley, passes through the Irvington Tunnel and enters the distribution system in the Bay Area.

Most of San Francisco's water is not filtered. It is only disinfected with chloramine, a combination of chlorine and ammonia. The chlorine is injected into the water at Tesla Portal, just east of the Coast Range Tunnel; and ammonia is added to the water in the Sunol Valley. The water not released directly from Hetch Hetchy—emanating instead from Calaveras Reservoir, San Antonio Reservoir, or the various reservoirs on the Peninsula—passes through conventional water-treatment plants, where it is filtered and then disinfected. San Antonio and Calaveras releases are treated at the nearby Sunol plant.

FIGURE 5-7
The SFPUC's Tuolumne River hydropower facilities



Source: Bureau of Reclamation

Releases from Crystal Springs, Pilarcitos, and San Andreas Reservoirs on the Peninsula are treated at the Harry Tracy plant in San Bruno. Presently, these plants are not large enough to filter and treat all releases from Hetch Hetchy.

Typically, releases from the Cherry and Eleanor Reservoirs do not directly enter San Francisco's water-supply system. They flow instead into Don Pedro Reservoir, meeting San Francisco's water rights' obligations to the Turlock and Modesto Irrigation Districts and thereby allowing diversions from Hetch Hetchy Reservoir. Releases from Cherry also generate hydropower at Holm Powerhouse, often on a schedule that allows whitewater boating on the Tuolumne River in the summer. There is a small canal connecting Cherry Reservoir and Early Intake Reservoir, which, under rare circumstances, has been used to convey water to the Bay Area.

Hydropower operations

San Francisco has been generating—and selling—hydropower from the Tuolumne River since the completion in 1918 of Early Intake Powerhouse and the Lower Cherry Creek Aqueduct, which delivered water from Cherry and Eleanor Creeks. Constructed to supply reliable power to the dam-construction efforts, Early Intake also yielded revenues from commercial sale of electricity. A series of progressively larger and more modern hydropower facilities were added over the succeeding decades. The current system was completed in 1988 with the addition of a third generator at Kirkwood powerhouse.

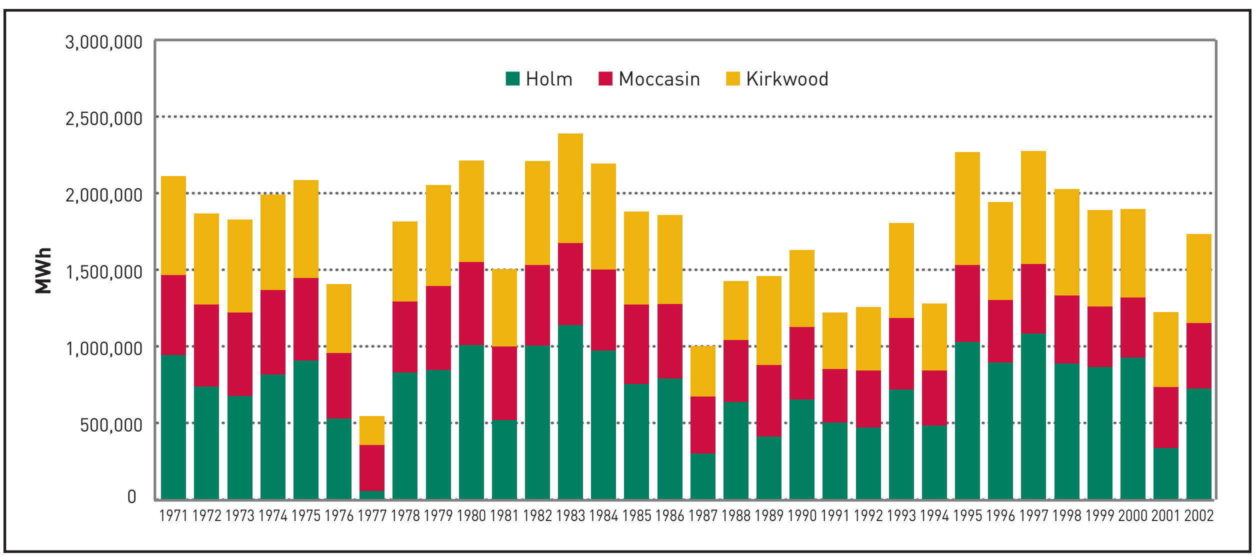
Today San Francisco operates three powerhouses—Moccasin, Holm and Kirkwood—along the Tuolumne River (see Figure 5-7). Their seven turbines are capable of collectively generating at a rate of up to 401 MW.[3] Kirkwood powerhouse is operated as a "base-load" facility, normally producing power at a constant rate, 24 hours per day. Moccasin and Holm powerhouses, by contrast, provide "peaking" power, concentrating energy production during those hours of the day when electricity is most valuable. According to the San Francisco Electricity Resource Plan, this system produces 1,700 million KWh in years of average rainfall.[4]

Hydropower production is highly variable, however, fluctuating from year to year with the amount of precipitation and the rate at which the winter snowpack melts. This variability is illustrated in Figure 5-8, which shows annual production by powerhouse for water years 1971–2002. Over the last three decades, annual energy produced at San Francisco's Hetch Hetchy powerhouses has ranged from 544 million KWh in the drought year of 1977 to 2,391 million KWh in 1983. But one consistent feature across all water-year types is that average generation is highest in May or June, when the spring runoff typically peaks.

The hydropower of San Francisco's system is essentially a byproduct of its water-supply operations, with flows scheduled to meet water users' needs rather than to take advantage of daily and seasonal variations in electricity prices. In this regard, the City's hydropower operations differ from those of comparable facilities elsewhere in California, which are owned by electric utilities and operated to maximize power-sales revenues. In most years, the demand for electricity is greatest and power is most valuable in August and September; thus hydropower operators generally try to conserve stored water for generation during hot summer afternoons. San Francisco's power production tends to decline during those months, however, as illustrated in Figure 5-9.

About a third of this electricity is used by public facilities, including the San Francisco International Airport, the San Francisco Municipal Railway (Muni), the Port of San Francisco, San Francisco county hospitals, the Recreation and Parks Department, street lighting, the Moscone Convention Center, and the City's water and sewer utilities. Until recently, much of the remainder was sold to the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) under long-term contracts at rates below

FIGURE 5-8
Annual production by powerhouse: SFPUC Tuolumne River system



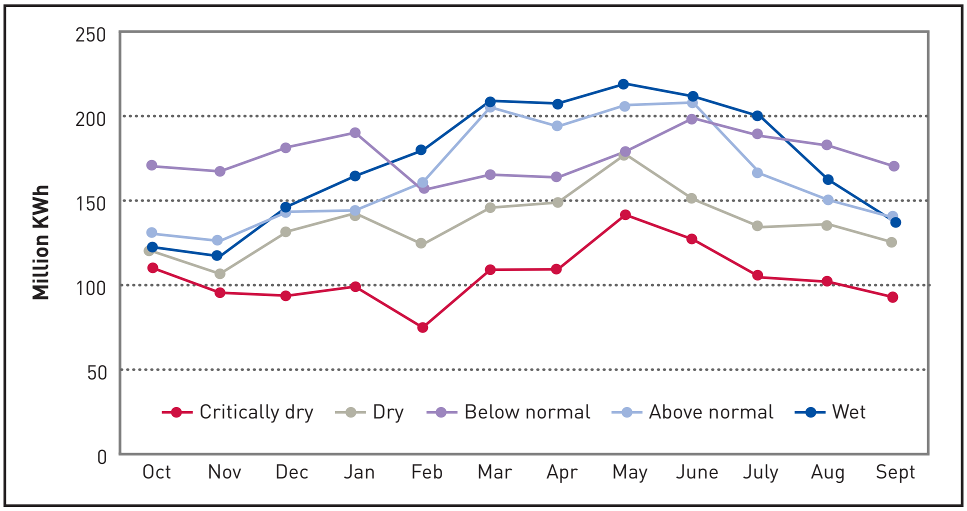
The SFPUC's Tuolumne River hydroelectric plants can produce 1,700 million KWh in years with average rainfall, but output varies widely from year to year.

Source: United States Department of Energy, Energy Information Administration market prices, as mandated by the Raker Act. The Act also prohibits San Francisco from selling the Tuolumne's hydropower to investor-owned utilities such as Pacific Gas and Electric Company, but the City sells surplus power to other public entities as well.[5]

In most years, the SFPUC is a net seller of electricity, as illustrated in Figure 5-10. Although the Tuolumne's

FIGURE 5-9

Average monthly energy production by water year type, 1974–2002, SFPUC Tuolumne River powerhouses

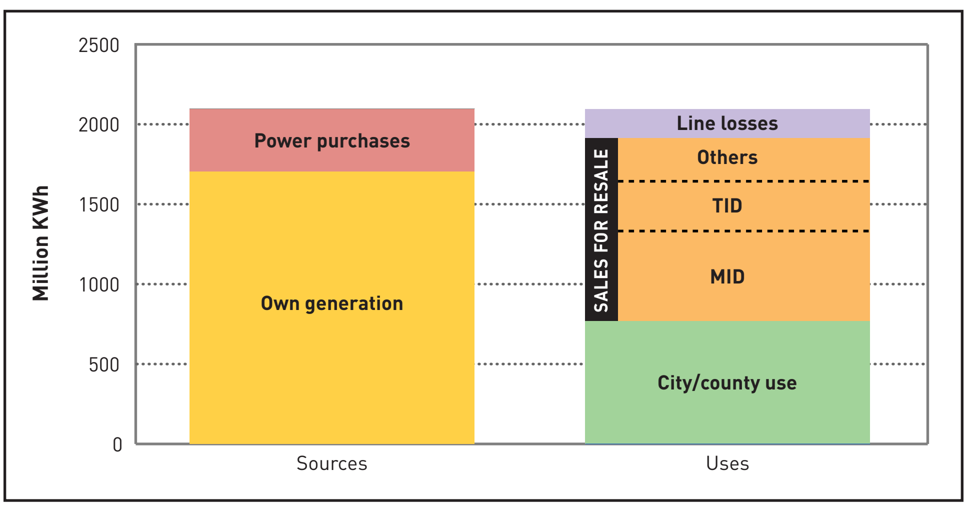


Hydroelectric production at the SFPUC's powerhouses typically peaks during the spring runoff, tapering off in late summer. This seasonal pattern reflects the SFPUC's focus on water supply operations. In hydropower systems that are operated to maximize power sales revenues, water is typically conserved to generate electricity in July–September, when it is most valuable.

Source: United States Department of Energy, Energy Information Administration

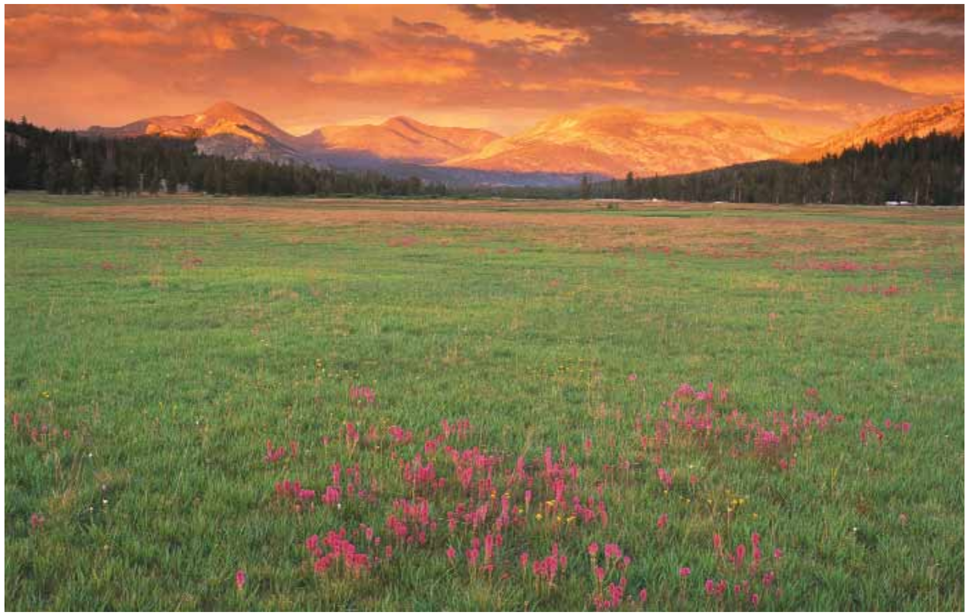
FIGURE 5-10

Sources and uses of SFPUC energy, 2002



In most years, the SFPUC is a net seller of electricity. Power that is not used in San Francico's public facilities is sold to the Turlock and Modesto Irrigation Districts and other power market participants. The SFPUC also purchases energy when the output from its Hetch Hetchy System is insufficient to meet its own needs and satisfy contractual obligations.

Source: United States Department of Energy, Energy Information Administration



CORBIS

High Sierra streams converge in Tuolumne Meadows, the headwaters of the Tuolumne River and a popular trailhead for backpackers exploring Yosemite's backcountry.

annual hydropower production exceeds the City's municipal energy needs, at times San Francisco must purchase energy to satisfy its own total demand and meet its contractual obligations to MID and TID. These purchases usually occur during the summer and fall months, when power production is reduced so that drinking water can be stored.[6] Currently the City has a long-term contract with the Calpine Corporation in order to achieve those ends.

Recreation and ecosystem protection

In addition to supplying water for urban, agricultural and power-generation uses, the Tuolumne River also provides recreational opportunities and environmental benefits. Tuolumne Meadows, high in the Yosemite National Park, is a popular destination for visitors, many of whom return home with tales of encounters with Yosemite's hungry, but normally harmless, black bears. Tuolumne Meadows also serves as a trailhead for hardy backpackers who traverse the high Sierra lakes or sometimes explore the "Grand Canyon of the Tuolumne" above Hetch Hetchy Valley.

Downstream of Hetch Hetchy Valley, beginning just below the confluence of Cherry Creek and the Tuolumne River, lie two world-class stretches of white-

LANCE LOUGEE

A paddle crew frolics on the Tuolumne River.

water. In spring and summer, experienced kayakers and rafters come to "run the T," floating the river's exciting and well known rapids by day and camping on the its banks by night.

The "Class 5" upper stretch, known as the Cherry Creek run, is for veteran river runners only, even when in the company of professional guides. The lower "Lumsden" run is a wet, fast and sometimes scary ride in May and June, when Sierra snowmelt often spills from the upstream reservoirs and provides high flows. As flows recede, the Lumsden run is less intimidating, but it is still a popular and exciting challenge; inexperienced river runners should not attempt to run the Tuolumne alone. On weekdays throughout the summer, the SFPUC makes hydropower releases from Holm Powerhouse that accommodate boating on both of these stretches.

The lower Tuolumne River, like other Central Valley streams, historically provided spawning habitat for chinook salmon and steelhead trout. But habitat degradation, drought, water diversions and other factors combined to drastically reduce spawning there; the low point was in 1991, when only 77 fall-run salmon returned to the lower Tuolumne. Since then, the efforts of government agencies, local communities, environmentalists and water districts, as well as protective minimum flows mandated by the Federal Energy Regulatory Commission, have improved the fishery's status significantly. Restoration projects in the 52-mile stretch between La Grange and the Tuolumne's confluence with the San Joaquin River continue, not only to improve fishery populations but also to expand the river channel's capacity to control flooding. Responsibility for providing instream flows below La Grange Reservoir is borne by the Turlock and Modesto Irrigation Districts.

CHAPTER 6

Alternative water-system components

This chapter describes a variety of components, for possible use in place of the Hetch Hetchy Reservoir, that would maintain or even improve the reliability and safety of San Francisco's water-supply system. Most of these components are already being considered—either in the SFPUC's Water Supply Master Plan, its Capital Improvement Program (CIP), or both[1]—as they could enhance system performance even if Hetch Hetchy Valley were not restored. Such improvements are evaluated without expansion of local conservation and recycling programs, and *with* significant increases in Bay Area water use over the next 25 years—though a final plan should include serious examination of these issues.

The components fall into three basic categories:

- **Conveyance.** Establishing reliable conveyance from all potential sources of supply is the best way of ensuring uninterrupted delivery of water to the SFPUC's Bay Area customers. But at present, SFPUC does not have direct access to most of its water storage in Sierra Reservoirs. Also, as addressed in detail by the CIP, in many places the system's reliance on a very limited set of tunnels and pipelines makes it too vulnerable to earthquakes, droughts, and other adverse events.
- **Supply.** Even without Hetch Hetchy Reservoir, the total storage capacity in SFPUC reservoirs would be more than three times its annual delivery objectives. In dry years, however, the SFPUC's water rights are very limited, and alternative supplies would be needed. This report examines alternatives for providing those supplies through increased local surface storage, groundwater exchanges, or transfers, but acknowledges that other options are available as well.
- **Treatment.** The existing SFPUC system applies conventional water treatment methods only to its releases from its Bay Area reservoirs; it is not required to filter its Tuolumne River supplies and therefore does not have the physical capacity to do so. Under the restoration alternatives considered in this report, significant supplies would be diverted from locations downstream of Hetch Hetchy Valley and the SFPUC would expand its conventional treatment capacity to cover all of its supplies.

Conveyance options

While Hetch Hetchy is the best-known component of San Francisco's present system, it holds less than 25 percent (360,000 out of a total of 1,533,000 acre-feet) of total system storage. But given its limited conveyance and treatment capabilities, it is often difficult for the SFPUC to make full use of its water storage in the other reservoirs—Cherry, Eleanor and Don Pedro—in the Tuolumne watershed. Getting full access to these supplies is critical to maximizing the reliability of SFPUC's water supply, with or without Hetch Hetchy Reservoir.

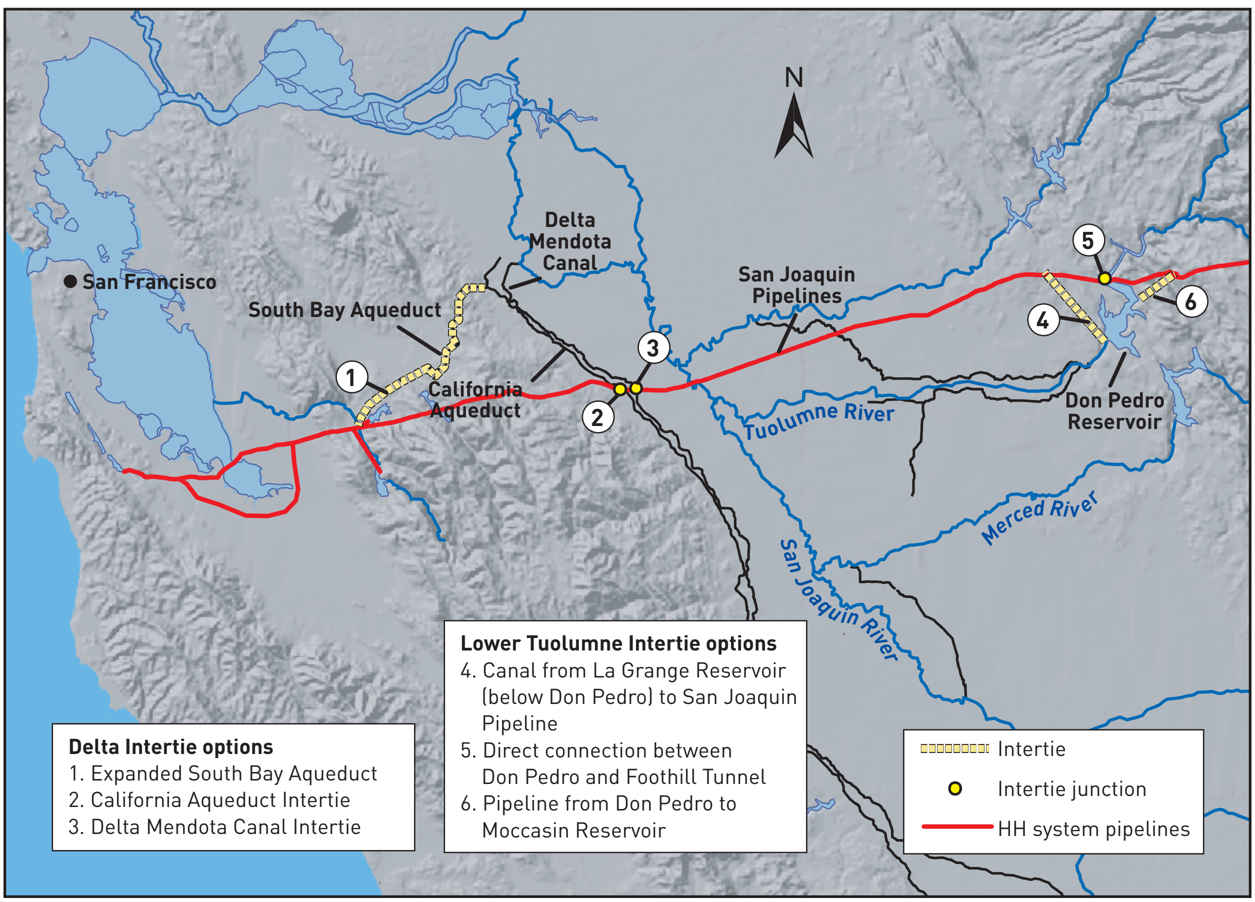
Under all restoration alternatives, San Francisco would continue to divert Tuolumne River flows during winter and spring months, and diversions might even be increased under some circumstances and stored in local reservoirs closer to Bay Area customers. Diversions from the Tuolumne River in the summer and fall would have to be made farther downstream, drawn from the SFPUC's supplies stored in other Tuolumne watershed reservoirs.

The simplest approach would be to build a new intertie between the Tuolumne River and San Francisco's aqueduct. If the intertie were at or below Don Pedro Reservoir, the City would have access to its supplies stored in Don Pedro itself, as well as upstream in Cherry and Eleanor Reservoirs. Alternatively, water could be released from Don Pedro Reservoir, flow down the Tuolumne and San Joaquin Rivers to the Sacramento-San Joaquin Delta, and be diverted to the SFPUC via the state or federal export pumps. While the intertie to Don Pedro would provide higher-quality water already under San Francisco's control, an intertie to the California Aqueduct would establish a link to most water systems in the state and allow the SFPUC much greater flexibility in purchasing water from other water agencies or exchanging supplies. Constructing *both* interties would offer additional alternatives to San Francisco, and would help ensure reliable supplies in the future.

INTERTIE TO LOWER TUOLUMNE RIVER

Don Pedro Reservoir, completed in 1970, holds over 2 million acre-feet, almost six times the storage of the

FIGURE 6-1
Potential locations for lower Tuolumne or Delta intertie



An intertie on the lower Tuolumne River could provide the SFPUC access to more than 1,000,000 acre-feet of water supply stored in Cherry and Eleanor Reservoirs and its water bank in Don Pedro Reservoir. An intertie to the State-federal Delta system could provide access to additional supplies, particularly in critically dry years or under emergency conditions, but would require negotiation with a variety of agencies which rely on supplies from the Delta.

TIM CONNOR

San Francisco's water bank in Don Pedro holds more than twice as much water as Hetch Hetchy Reservoir.

Hetch Hetchy Reservoir. While San Francisco owns up to 740,000 acre-feet of "water bank" storage in Don Pedro, the SFPUC does not currently draw this water directly. Rather, when the SFPUC diverts water upstream that belongs, under the water-rights criteria, to the Turlock and Modesto Irrigation Districts, it repays these districts from its bank.

San Francisco shared the cost of constructing Don Pedro Dam with the Turlock and Modesto Irrigation Districts through a complex set of agreements. As a result, SFPUC has access to storage in Don Pedro even when Tuolumne flows are below the levels at which it possesses recognized water rights. The City has no infrastructure for conveying its Don Pedro supplies to the Bay Area, however, nor has it established the legal right to build any such infrastructure. Thus construction of an intertie between Don Pedro reservoir and the SFPUC's conveyance system would require the active cooperation of the Turlock and Modesto Irrigation Districts.

Without storage in the Hetch Hetchy Reservoir, the SFPUC might divert directly from its bank in Don Pedro Reservoir (assuming that the aforementioned legal and infrastructural issues were resolved). There are in fact several ways that the SFPUC's supplies in Don Pedro Reservoir could be moved into the Hetch Hetchy Aqueduct for transport to the Bay Area, either for immediate use or storage in local reservoirs. Water could be:

- pumped directly from Don Pedro into the Foothill Tunnel, which runs directly beneath the reservoir;
- released through the Don Pedro Powerhouse and diverted farther downstream, perhaps via a new pipeline or canal from La Grange Reservoir to the Hetch Hetchy Aqueduct;
- pumped to Moccasin Reservoir (the entrance to the SFPUC's Foothill Tunnel), where present-day releases from Hetch Hetchy enter the aqueduct.

Schlumberger Water Services has estimated that constructing such an

TIM CONNOR

The California Aqueduct carries water from the Sacramento-San Joaquin Delta to a number of Bay Area communities and much of urban Southern California.

intertie directly to Don Pedro Reservoir, with the capacity to pump up to 407 cfs, would cost $29.7 million. Incorporating estimates for engineering, legal and administrative costs, and a standard range for the uncertainty of construction factors indicates that the cost of the intertie could range from $25 million to $53.5 million (see Appendix A).

INTERTIE TO THE STATE WATER PROJECT

Most of California diverts at least some of its water supply from the Sacramento-San Joaquin Delta, but the SFPUC has rarely done so, even though its San Antonio Reservoir is physically connected to the Delta via the State Water Project's South Bay Aqueduct. In the future, however, releases from San Francisco's water bank in Don Pedro Reservoir could be timed to coincide with diversions from the Delta.

Delta pumping plants are often operated at full capacity, but San Francisco's most critical needs might coincide with periods when some spare capacity is available.[2] Delta pumping constraints are most restrictive in the spring, when the SFPUC would normally be able to divert the Tuolumne's flows. During wet years, when these plants are often at full capacity as they move water supplies from northern California to urban southern California and irrigated agriculture in the Tulare Basin, San Francisco's needs for diversion would be smallest. Of course, SFPUC could also pump Delta supplies, when available, into its local storage reservoirs for delivery at a later time.

With improved access to its Tuolumne River supplies, an intertie to the State Water Project's California Aqueduct would not be used in most years. In critically dry years, however, such an

> The San Francisco Public Utilities Commission diverted 71,000 acre-feet from the Delta in 1991 and 1992, when its storage at Hetch Hetchy as well as its water bank in Don Pedro Reservoir reached low levels.

intertie would allow the SFPUC access to purchase supplies from a wide variety of agencies throughout the state. Without improved access to its Tuolumne River supplies, the SFPUC would need to use an intertie to the State Water Project much more frequently, requiring significant negotiations with SWP contractors.

Supply alternatives

The supply alternatives discussed below—increased local surface storage, groundwater exchange and transfers from willing sellers—are options that urban water districts throughout California have been adopting in recent years as they have diversified their portfolios to assure reliable water supplies for their customers. Other options should be considered as well; for example, the SFPUC and its customers are in the midst of a comprehensive effort to identify and implement cost-effective conservation measures.

SFPUC

MIKE MULLEN

Calaveras Reservoir (top) lies on a tributary of Alameda Creek (bottom). Expansion of the reservoir would create challenges for protecting sensitive species in the watershed, but also opportunities to provide enhanced flows for native steelhead restoration in nearby Alameda Creek.

LOCAL SURFACE STORAGE

The SFPUC owns five principal storage reservoirs in the Bay Area, with a total capacity of about 239,000 acre-feet, which could be expanded to offset the storage capacity lost if Hetch Hetchy Valley were restored. The most obvious opportunity is the expansion of the Calaveras Reservoir—at 97,000 acre-feet, the largest of the SFPUC's Bay Area reservoirs—which must be rebuilt anyway because it has been declared unsafe by the state's Division of Safety of Dams (a unit of California's Department of Water Resources). The SFPUC has proposed that the dam be increased to hold as much as 420,000 acre-feet, an increase that is nearly equivalent to the storage capacity of Hetch Hetchy Reservoir.

For the analysis in this report, Schlumberger Water Services has reviewed the SFPUC's investigation of an expanded Calaveras Reservoir and has estimated that the cost of reconstruction would be $23 million (to rebuild Calaveras at its current size of 97,000 acre-feet) or $90 million (to enlarge it to 420,000 acre-feet). The inclusion of additional expenses—for engineering, legal and administrative costs, and a standard range for the uncertainty of construction factors—indicates that rebuilding the reservoir at its current size would cost from $19.3 million to $41.4 million and that enlarging the reservoir to 420,000 acre-feet would cost between $75.6 million and $162 million (see Appendix A).

In addition, Schlumberger has estimated that the cost of building facilities to pump up to 204 cfs of Tuolumne supplies into Calaveras would be $43.4 million. Incorporating estimates for engineering, legal and administrative costs, and a standard range for the uncertainty of construction factors indicates that the pumping station and pipeline would cost from $36.5 million to $78.2 million (see Appendix A).

The SFPUC, in its Water Supply Master Plan and supporting documents, has also considered a long list of other new or expanded storage sites. For example, it has investigated a partnership role in the proposed expansion of Los Vaqueros Reservoir in Contra Costa County.

GROUNDWATER EXCHANGE

Many agricultural and urban water agencies throughout California rely on groundwater as part of their long-term water supply for the simple reason that groundwater storage increases a system's reliability and flexibility. San Francisco's Water Supply Master Plan has also identified groundwater opportunities—in the Westside Basin in San Francisco, Daly City and San Bruno, as well as in exchange programs throughout the Central Valley and in the Tuolumne watershed.

In the latter case, diversions from Don Pedro would be made during wet years to replenish groundwater storage. In dry years, surface-water diversions from Don Pedro would decrease and groundwater pumping would increase. Such changes in Don Pedro operations for the management of groundwater resources would require agreements with the Turlock and Modesto Irrigation Districts—whose officials might in turn act as intermediaries for deals with other districts in the eastern San Joaquin Valley—together with incentives for the area's agencies and landowners to participate.

Schlumberger Water Services has evaluated the physical potential of groundwater-management opportunities in or near the lower Tuolumne watershed. Schlumberger estimated total costs of $119.2 million to install infrastructure for a 400,000 acre-foot groundwater bank, with extraction capability of 200 cfs and recharge capability of between 283 and 386 cfs. Incorporating estimates for engineering, legal and administrative costs, and a standard range for the uncertainty of construction factors indicates developing the lower-Tuolumne groundwater bank would incur a total cost between $100.1 million and $214.5 million (see Appendix A).

Alternatively, the SFPUC could bank groundwater in a number of locations throughout the Central Valley. Under such an agreement, dry-year supplies would likely be provided through a State Water Project intertie.

In any case, while significant new groundwater-storage capacity might be developed as one way of replacing the storage in Hetch Hetchy Valley, it would probably not be accessed during most years. This supply could, however, provide important additional capacity during dry years and extended droughts.

TRANSFERS

With or without the storage provided by O'Shaughnessy Dam in Hetch Hetchy Valley, the biggest challenges generally facing water managers in California, and the SFPUC in particular, arise in dry years when the perennial conflicts between users of water for beneficial agricultural, urban and environmental purposes are exacerbated. But in some parts of the state, these conflicts have been resolved, and agreements between water-rights holders and buyers have helped to improve water-supply reliability while respecting legal ownership rights. Such transfers are not easy to negotiate, and for a variety of reasons—including a lack of clarity over who "owns" the water, a perceived weakening of rights when they are leased or sold, and potential impacts on third parties and the environment. Nevertheless, the potential benefits of agreements between willing sellers and buyers have made transfers a significant part of water portfolios for many districts.

Analysis for this report considers potential transfers from agricultural districts to the SFPUC during dry years. As in the case of groundwater, the simplest water transfers would involve agreements with water rights holders in the Tuolumne River area. With an intertie to the California Aqueduct, however, the SFPUC could purchase water from a wide variety of sellers statewide.

It is not known what the costs of these transfer agreements would be. The price per acre-foot of water purchased only in dry years would likely be significantly higher than if transfers were executed every year or in wetter years. For the purpose of this report's analysis, we assume transfer costs of $500 per acre-foot—a conservative estimate that is significantly higher than the transfer and groundwater-banking costs identified in Chapter 3.

Expanded water-treatment facilities

Whatever the restoration alternatives pursued, San Francisco would have to filter all of its supplies. But to do so, the SFPUC would need to increase treatment capacities beyond the levels identified in its CIP.

While a variety of locations, either in the Bay Area or the Central Valley, might be suitable for the expanded treatment facilities, this report assumes that the increase would occur at the SFPUC's existing Sunol Treatment Plant. Schlumberger Water Services has estimated that expanding the capacity of the plant by 160 million gallons per day (beyond the SFPUC's planned 80 million gallons per day expansion) would incur a total cost of between $134 million and $288 million (see Appendix A).

Integrating water-system components

Combining many of the components described above could not only preserve the level of reliability currently provided by O'Shaughnessy Dam and Hetch Hetchy Reservoir, but meet projected increases in water-delivery objectives as well. They could also provide the SFPUC with additional options in case its San Joaquin pipelines were rendered inoperable.

Chapter 7 examines several possible alternatives, using computer-based simulation modeling, for these components' integration into the SFPUC water-supply system. The total costs of implementing these scenarios, including the costs of forgone hydropower and additional water treatment, are provided in Chapter 10.

CHAPTER 7

Equivalent water-supply reliability

This chapter analyzes potential alternatives for operating the San Francisco Public Utilities Commission (SFPUC) system using computer-based simulation models. First we compare simulated operations with actual operations; that is, the analysis considers the system in its present incarnation, with Hetch Hetchy Reservoir in place and currently available water-delivery capability unchanged. A second simulation, with Hetch Hetchy Reservoir still in place, assumes a potential future system with increased water deliveries made possible by implementation of some of the expansion-oriented elements of the SFPUC's Capital Improvement Program (CIP). Both of these "base" simulations include not only the delivery of water to customers but assume that additional supplies are in storage, at all times, as insurance against drought.

The two base cases are then compared to a variety of "restoration" alternatives that simulate system operations *without* Hetch Hetchy Reservoir. These simulations first calculate, on a monthly basis, how much of the Tuolumne River flow could be diverted at the SFPUC's Early Intake Dam (between Hetch Hetchy and Don Pedro Reservoirs); and the amount of water that could be withdrawn at a downstream diversion point at or below Don Pedro Reservoir. These downstream diversions are constrained, in all model runs for the alternative cases, so that total system minimum-storage levels are consistent with base-case conditions. Alternative supplies would be needed to meet any remaining demands. The analysis presented below shows how often and to what extent such supplies would be needed, as well as how they might be integrated into system operations.

Overview of simulation modeling

It is standard practice to use computer-based simulation models to evaluate shifts in water-system performance that may result from infrastructural, demand, or operating-requirement changes. The state-federal CALSIM is the most commonly used model in California's Central Valley, but it is designed to focus on the operations of the State Water Project and the federal Central Valley Project.[1] Also, while CALSIM includes Don Pedro Reservoir, operations of the Turlock Irrigation District (TID) and Modesto Irrigation District (MID), and lower Tuolumne River flows, it does not include Hetch Hetchy Reservoir, other SFPUC upstream reservoirs, or the delivery of Tuolumne supplies to the Bay Area. Thus it could not be used as the principal model in this study.

An alternative option was the HHSM-LSM model, which the SFPUC generously provided to Environmental Defense (under a proprietary agreement). But while HHSM-LSM was useful for understanding the capabilities of the SFPUC's existing system, it proved difficult to modify for evaluating restoration alternatives.

To efficiently assess system reliability under a range of possible alternatives, Environmental Defense developed its own model—TREWSSIM (Tuolumne River Equivalent Water Supply Simulation). TREWSSIM includes data and methodologies found both in CALSIM and HHSM-LSM, and it accommodates the alternative components developed for this study. Also, TREWSSIM can simulate operations not only of the SFPUC but also of TID and MID, with and without O'Shaughnessy Dam.[2]

Like CALSIM, TREWSSIM simulates operations using a monthly time step and the natural flows that occurred between 1922 and 1994. This "historical hydrology" approach is standard practice for water supply planning in California.

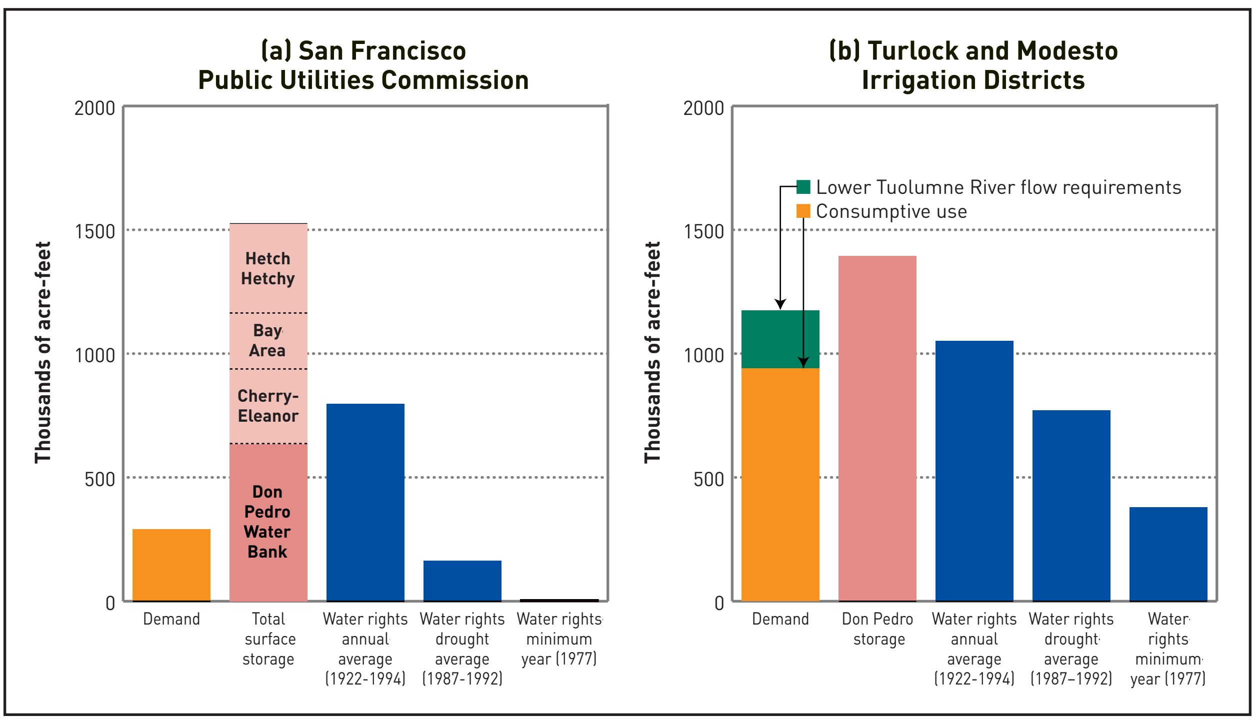
TREWSSIM incorporates existing infrastructure (such as reservoirs, canals, and pipelines), delivery objectives, and in-stream flow requirements. For this study, the model evaluates both the current water-delivery objective of the SFPUC (290,000 acre-feet per year) and its projection for 2030 (339,000 acre-feet per year).[3]

Modeling the performance of the SFPUC water system also requires modeling TID and MID operations, as all three rely on supplies from the Tuolumne River (see Figure 5-5 for a schematic of the SFPUC and Tuolumne River water-supply system). Figures 7-1a and 7-1b summarize the inflows, current delivery objectives and storage capacity both for the SFPUC and the Districts.

TREWSSIM's principal outputs include:

- Water deliveries to the SFPUC, TID and MID.
- Water storage for the SFPUC, TID and MID.
- Hydropower generation at the SFPUC's Kirkwood, Moccasin and Holm Powerhouses and the Districts' Don Pedro Powerhouse.
- The proportions of SFPUC water supplies derived from each source.
- Flow levels downstream of Don Pedro Reservoir, which affect the downstream fishery and, under some conditions, the potential for flooding in Modesto and surrounding areas.

FIGURE 7-1
Water supply, storage capacity and delivery overview



(a) In most years San Francisco's water rights are enough to meet its customers' needs. The SFPUC relies on storage in Hetch Hetchy, Don Pedro and other reservoirs to provide insurance against droughts, when its water rights are inadequate. (b) The Turlock and Modesto Irrigation Districts share the Tuolumne River with San Francisco, holding "senior" water rights that predate the City's. The Districts store water in Don Pedro for irrigation and domestic use and release flows below the reservoir to support the lower Tuolumne River and its fisheries.

Source: SFPUC and Bureau of Reclamation

Water deliveries under the "Existing Conditions" simulation are specified to be identical to those reported in the San Francisco Water Supply Master Plan (for the SFPUC) and in the Central Valley Project's Operations Criteria and Plan (for TID and MID). For the SFPUC, full objectives are generally met, though 10- to 15-percent shortages are imposed in some critically dry years.[4] TID and MID normally deliver supplies very close to their full objectives, though sometimes with the aid of groundwater pumping, especially in dry years.

For operating Don Pedro Reservoir—by far the largest reservoir in the combined system—TREWSSIM uses the evaporation, flood-control and minimum-downstream-flow parameters found in CALSIM. For operating Hetch Hetchy, Cherry and Eleanor Reservoirs, TREWSSIM uses the corresponding parameters provided by the SFPUC. In assessing alternatives that include the restoration of Hetch Hetchy Valley, TREWSSIM accounts for the SFPUC's flood-control criteria for operating Hetch Hetchy Reservoir by moving it downstream to Don Pedro Reservoir.[5]

Existing conditions: Meeting current needs with today's system

Figure 7-4a provides an overview of TREWSSIM's characterization of the SFPUC water deliveries under Existing Conditions. Over the course of an average year, about 34,000 acre-feet (12 percent) of the SFPUC's water supply comes from rainfall in Bay Area watersheds. The remainder is diverted from Hetch Hetchy Reservoir. These diversions are of two types: "flow" diversions (i.e., those that derive from the natural flow of the river) and "storage" diversions (i.e., when the Tuolumne River's flow is insufficient and water must be released from storage). Modeling indicates that an average of 149,000 acre-feet (51 percent) of the SFPUC's total water supply could be diverted directly from the river's flow and 104,000 acre-feet (36 percent) from storage. Finally, Figure 7-4a shows years in which the system cannot reliably meet full delivery objectives. These "shortages," consistent with the SFPUC's Water Supply Master Plan (April 2000), require the SFPUC to reduce deliveries by about 11 percent in one out of every nine years.[6]

For the SFPUC, a repeat of conditions similar to the six-year drought from 1987–1992—when its share of Tuolumne water rights was barely one-half of its delivery objective—is of great concern. Despite delivery reductions in five out of six of these years, storage levels dropped steadily throughout the period. Figure 7-3a shows this gradual but steady storage reduction, and compares the modeled values to actual historical values.

Consistent with actual experience, TREWSSIM projects the lowest storage value for the SFPUC system would occur in late 1992, shortly before California welcomed back large winter storms for the first time in seven years. While the water utility was indeed fortunate to have almost twice its average annual delivery objective at the end of a worst-case drought, generally the reduced storage would pose many problems for the current SFPUC system.

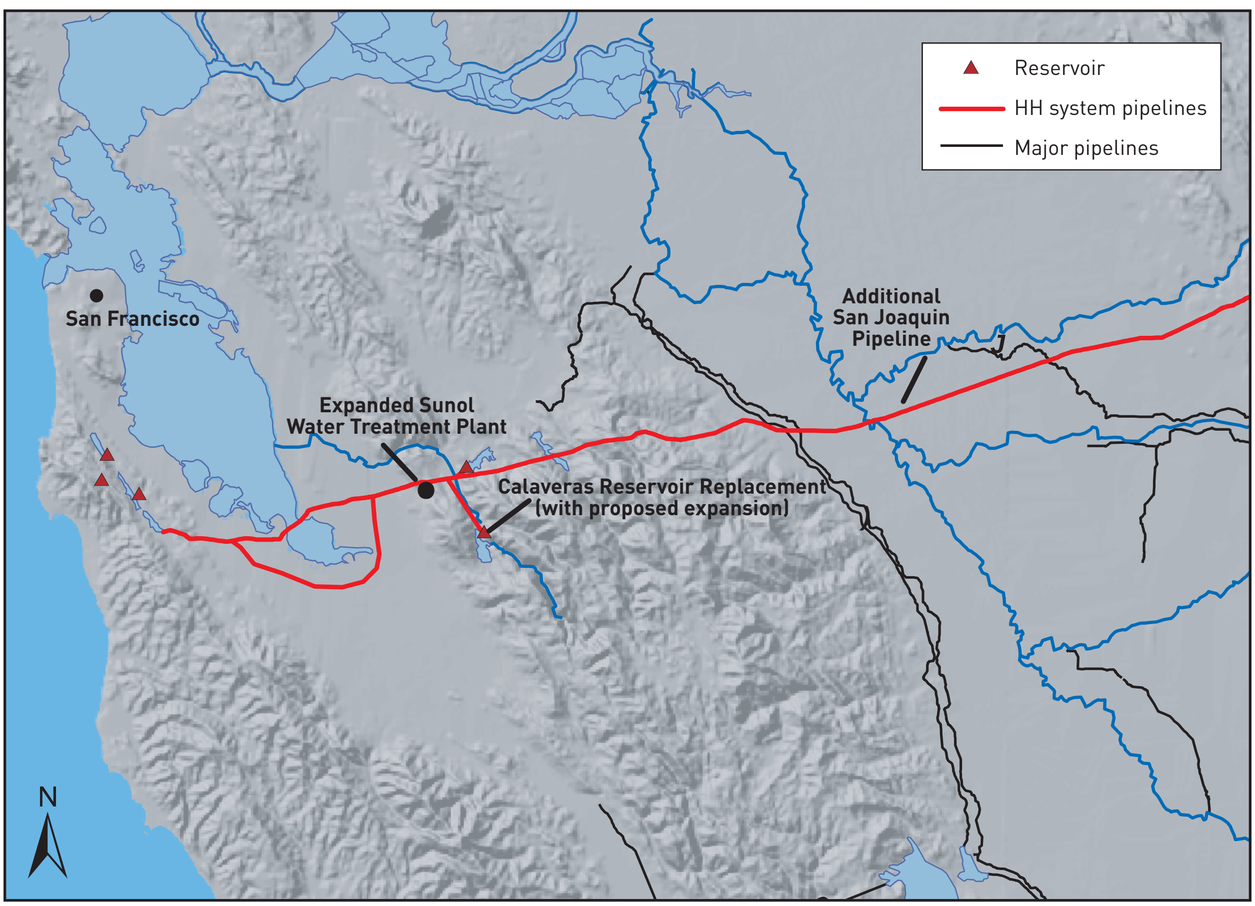
Most obviously, SFPUC's Tuolumne River water rights are almost nonexistent in some dry years, and the system is ill suited to make use of the Tuolumne supplies that it does have in storage. There is no physical connection between the SFPUC's customers and its water bank in Don Pedro; the ability to move water from Cherry and Eleanor Reservoirs to the Bay Area is very limited. Moreover, the SFPUC has limited ability to treat water from some of its own storage or alternative sources, largely because of its traditional reliance on diversions from Hetch Hetchy, which have been granted a rare exemption from filtration requirements by both the U.S. Environmental Protection Agency and the California Department of Health Services.

Potential future conditions: Meeting tomorrow's needs in the Bay Area

The SFPUC's Water Supply Master Plan (WSMP) projects that its customers' demand for water, resulting from population growth in San Mateo, Santa Clara and Alameda counties, will increase to 339,000 acre-feet per year by 2030. As the purpose of this report is to address what steps might be taken to restore Hetch Hetchy Valley, it is appropriate that both current and potential future levels of demand are considered. This increased level of demand is therefore incorporated in the TREWSSIM analysis presented below. It should be noted, however, that the SFPUC and its wholesale customers are currently reviewing these initial projections, with particular attention to possibilities for implementing water-use efficiency measures. Environmental Defense strongly supports aggressive water-use efficiency and looks forward to reviewing the agencies' findings.

In any case, the SFPUC has not clearly stated how it plans to meet future in-

FIGURE 7-2
Elements of the SFPUC's Capital Improvement Program that might overlap with a restoration plan for Hetch Hetchy Valley



creased demand, should the projections in its WSMP change little under the current review process. With the presence of expanded conveyance across the San Joaquin Valley and expanded storage in the Bay Area, however, it does appear that the SFPUC anticipates a Tuolumne River management regime that would sharply increase the diversions of Tuolumne River water to the San Francisco Bay Area. To evaluate alternatives for meeting increased water deliveries, we include in our Potential Future Conditions simulation the following three components of the SFPUC's $3.6 billion Capital Improvement Plan (CIP):

- Expansion of the Calaveras Reservoir to 420,000 acre-feet.
- Construction of a fourth pipeline to increase conveyance capacity of Tuolumne supplies across the San Joaquin Valley to 542 cubic feet per second.[7]
- Expansion of the capacity of the Sunol Water Treatment Plant from 160 to 240 million gallons per day.

Environmental Defense does not assume, for example, that Calaveras Reservoir will be expanded, nor do we take any position at this time on such expansion. This report simply uses the above three elements of the CIP to project one possible future for the SFPUC against which to compare alternatives that would accommodate restoration of Hetch Hetchy Valley.

Figure 7-4c provides an overview of how the SFPUC's 2030 objective would be met with the expansion of Calaveras Reservoir. In most years, under current demand levels, existing local supplies and diversions of Tuolumne supplies would together be sufficient to meet an expanded delivery level of 339,000 acre-feet. In critically dry years, however, storage at Calaveras Reservoir would need to be tapped in order to meet anticipated demand. Yet even the 323,000 acre-feet of additional storage provided by expanding Calaveras Reservoir from 97,000 acre-feet to 420,000 acre-feet would not be sufficient to allow the SFPUC to fully meet its projected water-delivery objective of 339,000 acre-feet per year while retaining the high level of carryover storage in the Existing Conditions alternative in all years. Fully meeting this objective for the drought between 1987 and 1992 would require an additional total supply of 77,000 acre-feet per year—462,000 acre-feet for the six year period—to alleviate the shortages under the current system and to accommodate the projected increase in demand.

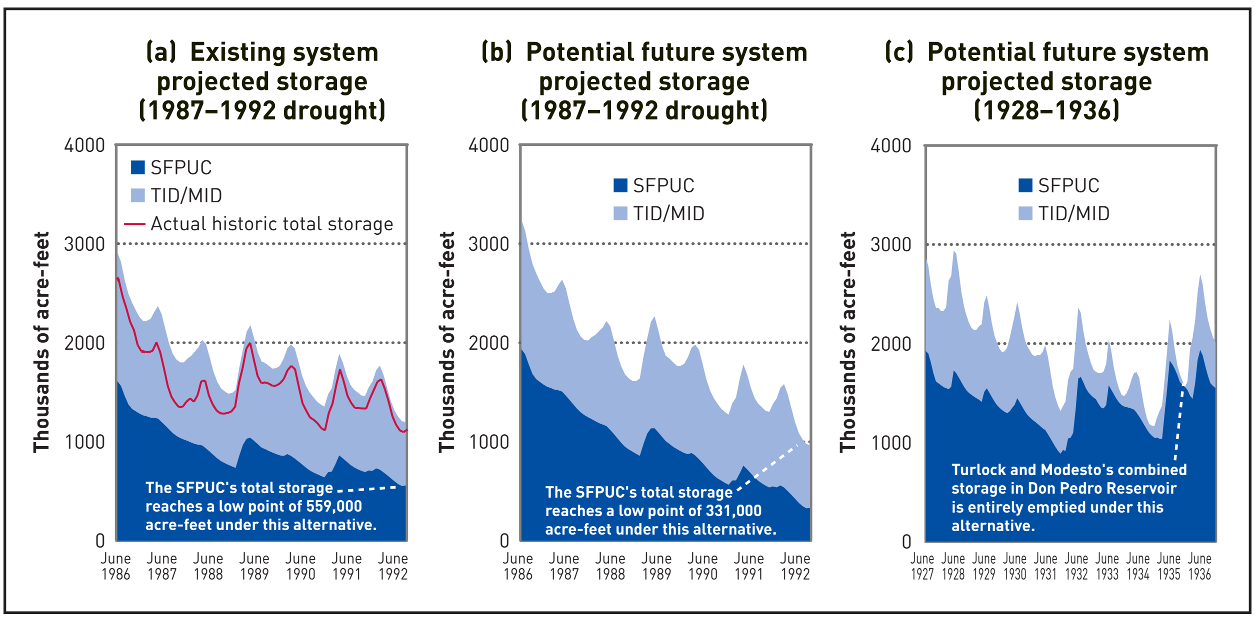
BANCROFT LIBRARY

The Oakdale Portal, pictured in this 1931 photograph, connects the SFPUC's Foothill tunnel and its San Joaquin pipelines. Adding a new fourth pipeline would improve reliability both by expanding conveyance capacity and providing a redundant pipeline (to facilitate repairs on the others).

The Potential Future Conditions alternative does assume, however, that the full delivery objective of 339,000 acre-feet is accomplished in all years. As a result, the system's simulated minimum end-of-drought storage falls from 559,000 acre-feet (under the Existing Conditions alternative) to 331,000 acre-feet—just under one year's supply—under the Potential Future Conditions alternative (see Figures 7-3a and 7-3b). For many systems, this amount of carryover storage would be deemed sufficient. The SFPUC, however, has little supply under its water rights in dry years, almost nonexistent alternative supplies, limited treatment facilities and limited conveyance-all of which leads it to rely heavily on significant carryover storage. The efficacy of relying on lower storage levels is not discussed further in this report, but the restoration alternatives under this future demand projection are constrained by TREWSSIM to retain a similar amount of storage under all conditions. The SFPUC's overall storage under this alternative during the 1987–1992 drought is shown in Figure 7-3b.

While all water moved from the Tuolumne system to the Bay Area under this alternative would be in strict accordance with the SFPUC's water rights, the modeling suggests that adverse impacts to the TID and MID could occur under these future conditions. Currently, the Districts rely on receiving water that accrues to the SFPUC under its water rights but that it is unable to use. Thus, when the SFPUC's water in Don Pedro Reservoir exceeds its maximum water-bank

FIGURE 7-3
Simulated drought-period storage values



(a) Compares simulated storage values for the SFPUC, TID and MID, under the Existing Conditions alternative, during a hypothetical repeat of the 1987–1992 drought. Because of the dry hydrology, exacerbated by limited Tuolumne River water rights, SFPUC's storage decreases steadily throughout the period, with only brief and minor occasional increases. (b) Shows simulated storage values for the SFPUC, TID and MID, under the Potential Future Conditions alternative, during a repeat of the 1987–1992 drought. Given the assumed expansion of Calaveras Reservoir, the SFPUC begins the drought period with more water in storage than under the Existing Conditions alternative. But because of the assumed increases in demand, the SFPUC ends the period with less water in storage. (c) Shows simulated storage values for the SFPUC, TID and MID, under the Potential Future Conditions alternative, during a repeat of the 1928–1936 period. The modeling suggests that, given certain hydrological conditions, increased diversions of Tuolumne water by the SFPUC under its water rights would leave less available to the Turlock and Modesto Irrigation Districts.

storage, it "spills" to the Districts. If the SFPUC diverts more water directly to its customers or stores water for later use in an expanded Calaveras reservoir, its water bank in Don Pedro Reservoir is less likely to spill.

Whether such spills occur is most likely to be relevant to the Districts in years when near-average precipitation follows a dry period. (In wet years, all parties have plenty of water. In dry years, the SFPUC's water bank does not spill.) Comparing the Potential Future Conditions simulation to the Existing Conditions simulation, average annual spills of SFPUC's water bank decrease by 57,000 acre-feet (from 466,000 acre-feet to 409,000 acre-feet) and the Districts' average storage in Don Pedro decreases by 66,000 acre-feet (from 869,000 to 803,000 acre-feet).

During some periods, the Districts' storage would be reduced by 200,000 acre-feet or more. Under a repeat of the conditions of December 1935, for example, TREWSSIM modeling shows that the Districts would have no water in storage in Don Pedro Reservoir (See Figure 7-3c). Under such conditions, the TID and MID would probably conserve water by reducing allocations and asking farmers to switch to groundwater. More generally, the analysis indicates that increased diversions by the SFPUC do have the potential to diminish the Districts' water supply.

Simulation analysis of restoration alternatives

Operating the SFPUC water system without Hetch Hetchy Reservoir would require significant changes. Still, San Francisco's rights to Tuolumne River flows, as formalized under the Raker Act, would remain, as would more than 75 percent of the system's existing storage. It would be necessary to move water differently, however, as summer and fall releases from Hetch Hetchy Reservoir storage would no longer be possible. In most years, storage in other Tuolumne River watershed and Bay Area reservoirs would provide sufficient supplies. In dry years, additional supplies would be needed to maintain reliability for Bay Area customers.

TIM CONNOR

Run-of-river flows could be diverted from Early Intake Dam, where the SFPUC diverted its Tuolumne supplies prior to the completion of the Canyon Tunnel in 1967.

RUN-OF-RIVER DIVERSIONS

Without storing water in the Hetch Hetchy Valley, the SFPUC would still be able to use most of its Tuolumne River supplies by diverting the river's natural flow, mostly in the winter and spring, either directly to customers or to storage facilities in the Bay Area. These diversions would take place either at the current site of O'Shaughnessy Dam or downstream at Early Intake Dam, where the SFPUC diverted its supply prior to the completion of the Canyon Tunnel in 1967.

The single greatest factor in determining the feasibility of these diversions, of course, is sufficient natural flow throughout the year. (Other factors include the SFPUC's maximum conveyance capacity, storage capacity in Bay Area reservoirs, and customer demand in the Bay Area.) TREWSSIM analysis of the hydrologic record indicates run-of-river diversions could provide an average of 149,000 acre-feet annually, or about 59 percent of the SFPUC's total Tuolumne supply, under current conditions. Under Potential Future Conditions described, the additional conveyance, local storage and demand would accommodate a slight increase in run-of-river diversions to an average of 167,000 acre-feet.

USING AN INTERTIE TO DON PEDRO RESERVOIR

The remainder of the SFPUC's water supply would need to be diverted farther downstream. Don Pedro Reservoir, or immediately downstream of it, would be a logical location because it could provide the SFPUC with access not only to its stored water in Don Pedro but also to its supplies upstream in Cherry Lake and Lake Eleanor.[8] In addition, the SFPUC's Foothill Tunnel already runs directly under Don Pedro Reservoir. Diverting from Don Pedro, however, would require construction of an intertie between the reservoir and the SFPUC conveyance system, as well as the cooperation of TID and MID.

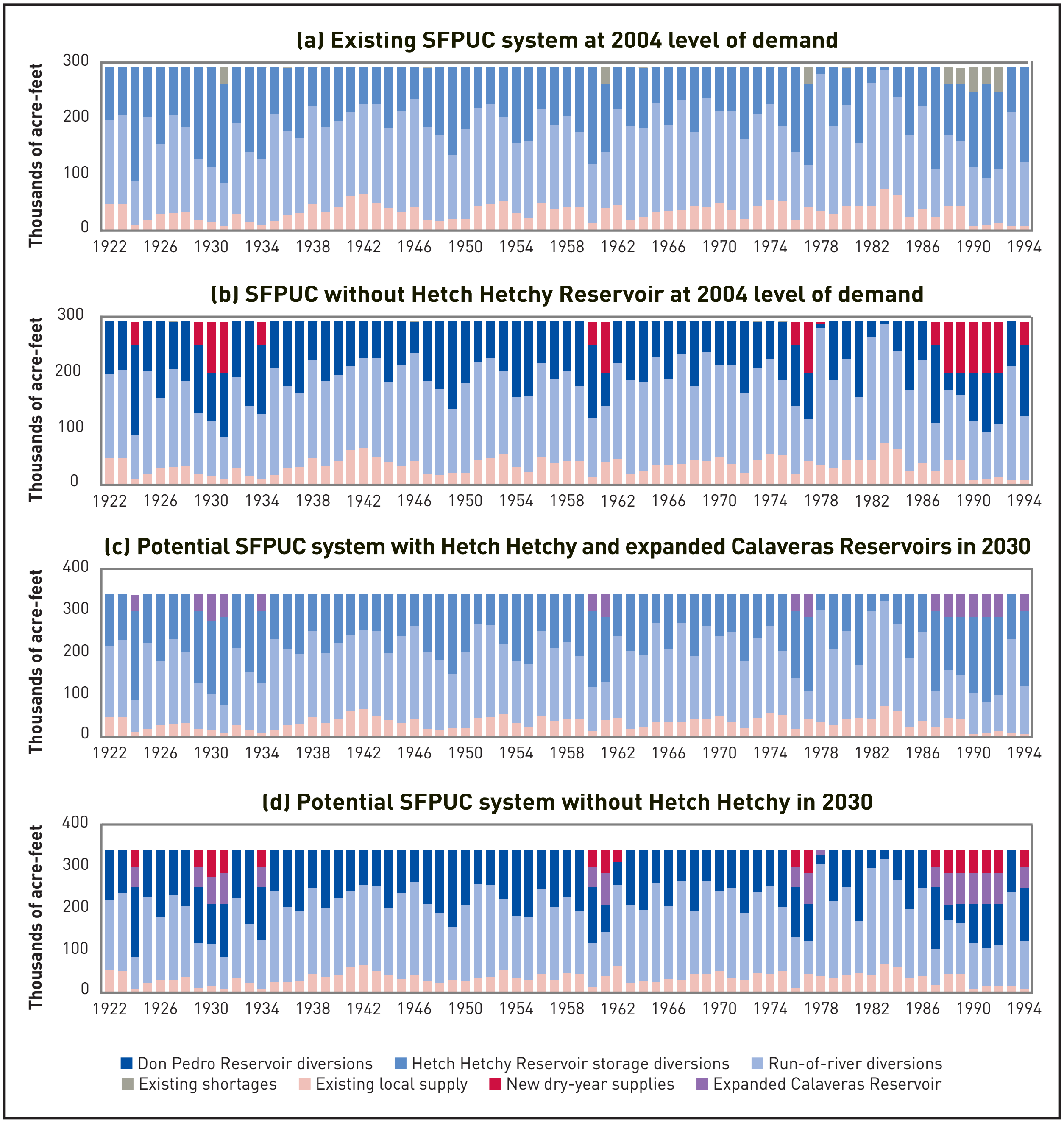
With an intertie in place, diversions of water released from the SFPUC's water-storage bank in Don Pedro would be sufficient to meet either current or potential future system demands in most years. Figure 7-4b provides an overview of the simulated mix of local water supplies, upper Tuolumne (run-of-river) diversions, and Don Pedro diversions that would together meet the current delivery objective of 290,000 acre-feet in all but critically dry years. Analysis indicates that these deliveries could be accomplished while maintaining a minimum carryover storage value that is similar to the Existing Conditions alternative value of 559,000acre-feet (see Figure 7-3a).[9]

Under the Potential Future Alternative (with an expanded Calaveras Reservoir), adding an intertie to Don Pedro would also allow the SFPUC to meet increased demand in most years. Figure 7-4d provides an overview of the anticipated supply mix that would be sufficient to meet the future delivery objective of 339,000 acre-feet in all but critically dry years, while maintaining a minimum carryover storage value that is similar to the Potential Future Conditions alternative value of 331,000 acre-feet (see Figure 7-3b.[10]

Under either the Existing Conditions or Potential Future Conditions alternatives, no additional supply is necessary to meet delivery objectives in most years. For either alternative, additional supplies would be necessary in critically dry years, or about 22 percent of the time. Under the Existing Conditions alternative, an average additional supply of 69,000 acre-feet would be necessary in years classified as "critically dry" to fully meet demands in every year. Under the Potential Future Conditions alternative, an average additional supply of

FIGURE 7-4

Simulated water supply sources for the SFPUC



(a) Under current operations, local supplies from runoff in Bay Area watersheds account for an average of 12 percent of total supply. The rest of the supply is diverted at Hetch Hetchy Reservoir, either from the Tuolumne River's flow or from storage. Without Hetch Hetchy Reservoir, the diversions from storage would not be possible. This figure also shows the existing shortages as projected by the SFPUC. (b) Without Hetch Hetchy Reservoir, diversions from a point lower on the Tuolumne River provide sufficient supply to the SFPUC in most years while maintaining carryover storage objectives. In critically dry years, additional supplies would be necessary in order to meet delivery objectives. (c) Under a projected future alternative that includes increased local storage as well as increased demand, the existing storage facilities would be sufficient to meet demand in most years. During critically dry years, however, expanded local storage would be needed in order to meet demand for Bay Area customers. As shown in Figure 7-3b, this alternative would result in lower carryover storage compared to Existing Conditions. (d) Under projected future alternatives that include both increased local storage as well as increased demand, Tuolumne River diversions (even without Hetch Hetchy Reservoir) and existing local facilities would be sufficient to meet increased demand in most years. In critically dry years, however, both expanded local storage and new supplies would be necessary to meet demand for Bay Area customers.

48,000 acre-feet would be needed. (This water-supply replacement value for critical years is slightly lower under the Potential Future Conditions alternative because it is modeled with a relaxed carryover storage constraint.)

EXPANDED LOCAL STORAGE

Expanding Calaveras Reservoir, as envisioned in the CIP, could replace most of the storage lost if Hetch Hetchy Valley were restored. The projected increase at Calaveras of 323,000 acre-feet (from 97,000 acre-feet to 420,000 acre-feet) is slightly less than the capacity of Hetch Hetchy Reservoir. Consequently, using the proposed increase at Calaveras alone as an offset to Hetch Hetchy Reservoir would result in slightly diminished overall system storage.

Figure 7-5a provides a summary of the simulated operations of Calaveras reservoir under this alternative. Releases from Calaveras for consumptive use are made under a variety of conditions. For example, some of these releases are made when natural inflow occurs and the reservoir is already full. The reservoir is most valuable in dry years, however, when its supplies can either be provided directly to customers or its storage can be used as insurance while allowing other reservoirs to be used more aggressively.

Model results project that an annual average of 36,000 acre-feet would be pumped into an expanded Calaveras, with a maximum annual value of 136,000 acre-feet. In addition to the cost of pumping water into Calaveras, it is anticipated that supplies released from the reservoir would be more costly to treat than supplies diverted directly from the Tuolumne watershed.

GROUNDWATER

In dry years, urban agencies throughout California either pump groundwater directly or exchange it with agricultural districts for surface water. As discussed in Chapter 3, urban and agricultural agencies have negotiated in recent years a series of such groundwater-exchange agreements, which provide water-supply reliability for urban areas and generate important revenue for agricultural areas.

From a physical perspective, a groundwater-exchange project with Tuolumne-watershed parties—including TID, MID, or other adjacent districts—would be straightforward and could allow additional surface-water diversions to the SFPUC from Don Pedro Reservoir. Alternatively, the SFPUC could enter into an exchange agreement with agencies throughout the Central Valley (though their supplies, diverted from the Sacramento-San Joaquin Delta, would probably require increased conveyance capacity between the SFPUC's aqueduct and the State Water Project or the Central Valley Project).

TREWSSIM modeling of a groundwater-exchange program to replace the supply currently provided by Hetch Hetchy Reservoir suggests that an annual average of 9,000 acre-feet, with a maximum annual value of 96,000 acre-feet, would be pumped. Under future conditions, modeling suggests that use of groundwater would increase slightly, averaging 15,000 acre-feet annually with a maximum use of 119,000 acre-feet. The modeling assumes that agricultural agencies would use the additional groundwater in some dry years, thus making additional surface water available to the SFPUC and its customers.

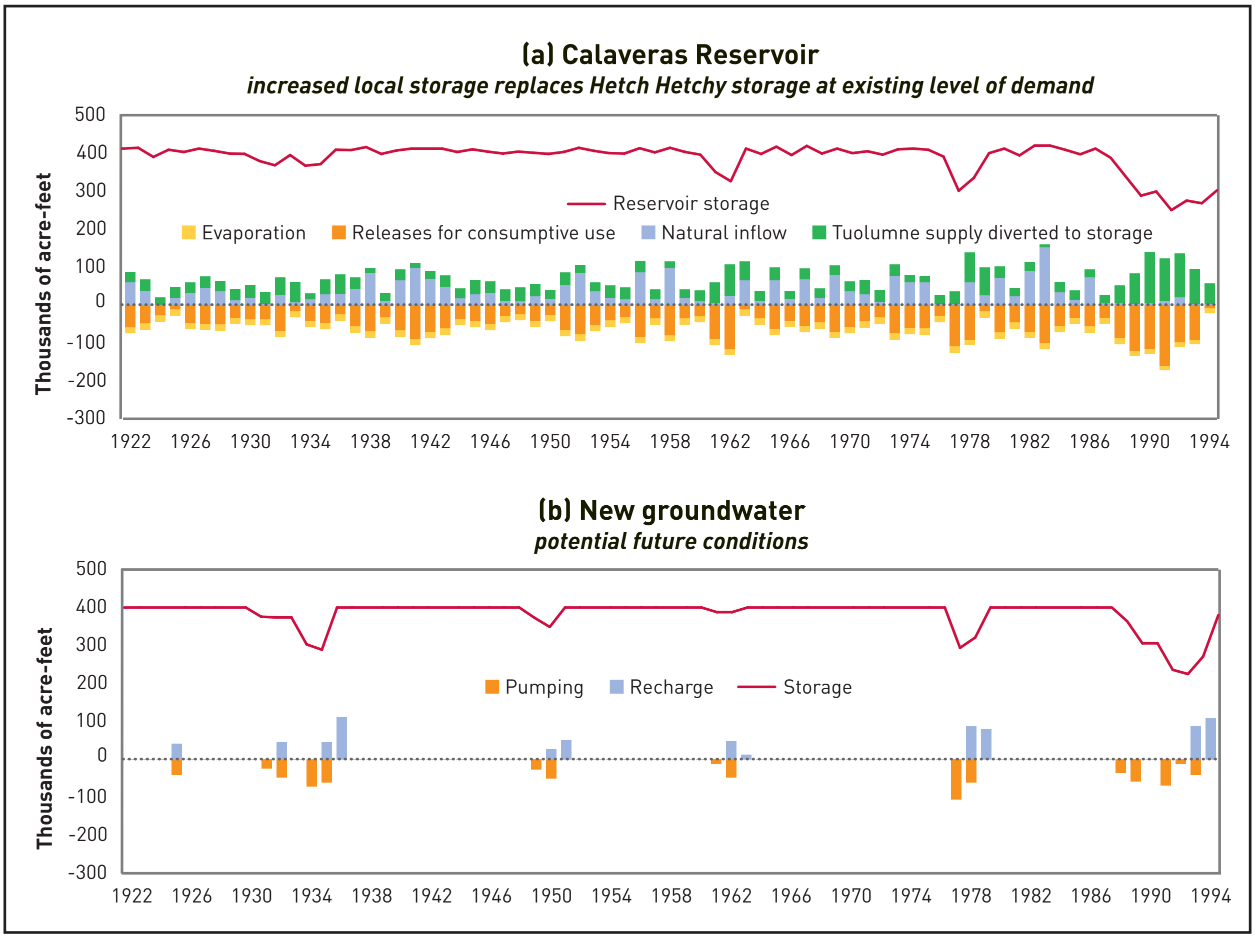
Figure 7-5b provides a summary of the simulated operations of new groundwater that would replace the storage lost with the restoration of Hetch Hetchy Valley. In most years, this additional groundwater would not be used. It would simply remain in storage as a backup supply and allow water agencies to operate other facilities more aggressively. Groundwater would be pumped during some dry years, but it would be replaced as quickly as possible.

The total costs of groundwater operations, combining the capital and operating costs provided by Schlumberger Water Services and the frequency of operation simulated by TREWSSIM, are provided in Chapter 10.

TRANSFERS

With an intertie to Don Pedro, transfers could play essentially the same role as groundwater exchanges in providing supply reliability to the SFPUC and its customers. Given that the SFPUC has ample supply in most years, a long-term agreement with a purchase option would probably best serve its needs. Under such an agreement, the SFPUC would pay a flat up-front fee or an annual fee for the right to purchase certain quantities at specific times, should the need arise, during the course of a dry year. In most years, no water would be sold. In dry years, the SFPUC would know in advance that it could purchase additional supplies. Under such agreements, a decision to exercise

FIGURE 7-5
Simulated operations



(a) Provides an annual summary of the simulated operations of Calaveras Reservoir. The reservoir would be kept full in most years to ensure its availability in case of drought. Also in most years, some part of the supply would be released to make space for natural inflow. (b) Provides an annual summary of the simulated operations of a new groundwater bank. The bank would be kept full under most conditions and seldom accessed. Its availability to provide replacement supplies, however, would allow water agencies to operate surface reservoirs more aggressively.

the option must normally be made by a certain date, so the sellers have ample opportunity to plan their own water use for the year.

TREWSSIM modeling of transfers to replace supply currently provided by Hetch Hetchy Reservoir suggests that SFPUC would purchase an annual average of 9,000 acre-feet, with a maximum annual value of 56,000 acre-feet. Under future conditions, modeling suggests that use of transfers would increase slightly, averaging 11,000 acre-feet annually, with a maximum annual use of 84,000 acre-feet. In a transfer program with an agricultural district, the seller could choose whether to switch to a less water-intensive crop, implement alternative irrigation technology, or permit fields to go fallow during years in which transfers take place.

In many parts of California, mistrust between urban agencies and the agricultural districts that hold senior water rights has prevented transactions, whether groundwater exchanges or transfers, that increase the efficient use of water for the benefit of both parties. As noted in Chapter 3, however, this mistrust has been fading in recent years as agricultural districts have found ways to assure themselves that they can retain local control of their water supplies while simultaneously providing needed revenue to their communities and assuring reliability for California's cities.

COMBINING ELEMENTS

Of course, a plan to restore the Hetch Hetchy Valley by replacing Hetch Hetchy Reservoir's storage is not limited to a single element, such as local storage, groundwater exchange or transfers alone. The plan might feature those elements in various combinations and degrees, and it might also include others—such as water conservation, reclamation, or enlargement of existing reservoirs—to replace the lost storage.

The results of simulations that include multiple elements show that this diversity makes for a more robust system. The combined use of transfers and groundwater exchanges, for example, puts less pressure on system storage during dry years.

DELTA CONVEYANCE

Alone or in conjunction with an intertie to Don Pedro Reservoir, the SFPUC could divert its Tuolumne supplies (together with supplies from other sources as well) farther downstream in the Sacramento-San Joaquin Delta. While SFPUC did divert Delta supplies in 1991–1992 through its connection to the State Water Project's South Bay Aqueduct, this option is not reliable with current infrastructure. The South Bay Aqueduct would need to be expanded, or an interconnection between the San Joaquin pipelines and either the California Aqueduct or the Delta-Mendota Canal would have to be built. Such a link would give the SFPUC broad access to the statewide water market and a greater opportunity to ensure reliable supplies, should Tuolumne supplies not be sufficient in certain years.

Diverting from the Delta on a regular basis could result in conflicts with other agencies that already do so, and it would require significant negotiation with the California Department of Water Resources, the U.S. Bureau of Reclamation, and their contractors. During dry years, however, conveyance capacity is generally available and could more easily be used to transport supplies obtained by the SFPUC under exchange or purchase agreements. Delta diversions might best be accomplished if used to supplement diversions using a Don Pedro intertie.

Transfers or groundwater exchanges to meet supply needs in critically dry years could be implemented via a Don Pedro intertie alone, as long as the agreement involved agencies within, or possibly adjacent to, the Tuolumne River watershed. If these additional supplies were obtained from other parties, however, a Delta intertie would be necessary. The costs for these two options are derived in Chapter 10.

Schlumberger Water Services has conducted preliminary modeling studies that evaluate using a Delta intertie to provide supplies to the SFPUC on a regular basis (i.e., without a Don Pedro intertie). These studies do not rely on scheduled releases of Tuolumne River water and thus result in impacts to other water supply agencies that would need to be resolved. A summary of these analyses is provided in Appendix A.

Reliability benefits of a diversified water supply

The amount of water remaining in storage at the end of a simulated drought period is a key indicator of a system's supply reliability. However, the needed storage capacity diminishes as access to additional supplies becomes available. For example, if a water agency has an option to purchase additional water during dry years, it has less need to retain a large supply of its own. Dry-year purchase agreements, in other words, could provide the same reliability as additional storage.

Thus while the SFPUC may prefer its own Tuolumne supply, it should very carefully consider how to access additional supplies in times of need. To guarantee access to water, either during a drought or after a catastrophic event such as an earthquake, the SFPUC should continue to pursue physical interconnections and purchase agreements with other sources of supply. Bottom line: Reliability can be achieved in a variety of ways.

CHAPTER 8

Water-quality analysis

Any viable plan to restore Hetch Hetchy Valley must assure that the quality of Bay Area residents' drinking water will not be diminished. As part of this investigation of water-supply alternatives, Environmental Defense retained Eisenberg, Olivieri and Associates (EOA) to assess the existing and future quality of water delivered by the San Francisco Public Utilities Commission (SFPUC), both with and without Hetch Hetchy Reservoir. Based on a review of raw (untreated) water-quality data from potential replacement sources, EOA determined "there does not appear to be any technical reason [why] the SFPUC Hetch Hetchy water-supply system could not be operated without the Hetch Hetchy Reservoir," though did recommend that further water-quality analysis be pursued concurrently with the examination of specific alternatives.

This chapter provides a brief overview of water-quality and treatment issues, a summary of EOA's findings, and the estimated costs for treating water from alternative sources. For a more detailed summary of EOA's findings, see Appendix B.

Overview of major contaminants and treatment

Contaminants that enter water-supply systems can pose both immediate and chronic threats to human health. Chronic risks are caused by a long list of chemicals, including lead, radon, arsenic and MTBE (methyl tertiary-butyl ether), while the most immediate risks tend to come from a range of microbiological contaminants, or pathogens. These protozoa, bacteria, or viruses generally cause mild or moderate gastroenteritis, but they can sometimes cause more severe illnesses and on rare occasions be fatal.

Two types of protozoa—giardia and cryptosporidia—are commonly associated with untreated or poorly treated water supplies. These parasites cause persistent diarrhea, and cryptosporidiosis in particular can be fatal to children, the elderly, or patients with compromised immune systems.[1] Both pathogens are resistant to chlorine disinfection.[2] The U.S. Environmental Protection Agency (EPA) has in the past several years promulgated new treatment rules for protecting water supplies from giardia and cryptosporidia. Compliance with these rules may involve one or more of a variety of technologies, including enhanced filtration and sedimentation to reduce turbidity and application of ozone and ultra-violet light.

Bacteria, which are smaller than protozoa and thus more difficult to filter thoroughly, cause typhoid and cholera—historically, among the greatest threats to human health through drinking water. These diseases, though still a serious threat in some parts of the world, have largely been eliminated in the United States. Other bacteria, including E. Coli, salmonella and shigella, can cause major health problems in untreated water or if a breakdown occurs in the treatment process. Normally, however, such bacteria are adequately treated with chlorine, chloramine or other forms of disinfection.

More than 140 viruses, including those responsible for hepatitis and meningitis, are known to infect people through their digestive tracts. While most of these viral infections are transmitted through food or direct contact, rotavirus and others are known to be transmitted through water supplies.

Many viruses are effectively eliminated by chlorine or chloramine disinfection. Some are resistant to these processes, though new treatment approaches using ozone or ultraviolet light may be effective against them.

In California, water quality is regulated by the EPA and the state Department of Health Services. The EPA has set National Primary Drinking Water Regulations (NPDWRs) for 16 inorganic and 54 organic chemicals.[3] The California Department of Health Services identifies seven chemicals as "of current interest, including arsenic and MTBE".[4] While high concentrations of arsenic found in wells in Bangladesh have caused a critical health problem there, arsenic is found in water systems only in certain areas of the United States, and usually in low concentrations. Disputes about acceptable levels of arsenic have most recently led to a new U.S. standard of 10 micrograms per liter, which will be implemented in 2006.

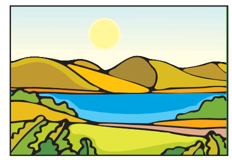
MTBE is a colorless liquid hydrocarbon that has been used to enhance gasoline. Its presence both in surface-water and groundwater supplies was a major factor in its incorporation into water-quality standards. Because MTBE is being phased out of gasoline production, it is not likely to be significant in future surface-water supplies, although it will likely persist in groundwater in some areas. Most water agencies have taken steps, such as prohibiting 2-stroke engines, to reduce or eliminate MTBE contamination in their reservoirs.

Chemical disinfection of water supplies can sometimes create unwanted side effects through the treatment processes' byproducts. For example, because water in the Sacramento-San Joaquin Delta contains both bromide and organic matter, treating these supplies with chlorine can cause formation of trihalomethanes (THMs), which are

FIGURE 8-1

Water treatment process

The treatment process removes or neutralizes micro-organisms, sediment, and disease-causing pathogens in order to leave water clear and safe for consumption. The water treatment process varies dependent both on the nature of the water source and the preferences and finances of the water agency controlling the treatment process.



Raw water

Screening. To begin the treatment process, water is pumped from a reservoir through screens to remove particulate matter and lower turbidity.

Coagulation/rapid mixing. This is a chemical process with rapid mixing in which charged metals are added to the water to "attract" and "trap" micro-organisms and other impurities.

Flocculation. This physical process assisting coagulation slowly agitates allowing the chemicals to interact with the impurities and form larger solids called "floc."

Sedimentation. The floc then settles to the bottom of the basin and is removed.

Filtration. The water is strained through a layer of activated carbon and sand to remove the small particles missed by screening, coagulation and flocculation.

Disinfection. The only impurities remaining should be the very small, potentially disease-carrying pathogens, which must be removed or inactivated by chemical disinfectants such as chlorine, ozone, and chlorine dioxide.

To distribution system

Source: Report of the Walkerton Inquiry, Part Two, Chapter 6: Drinking Water Treatment Technologies. pp. 189–208 suspected human carcinogens. As a result, some Delta users have switched from chlorine to other disinfection technologies, such as chloramine and ozone, though ozone reacts with bromide to form bromate—another carcinogen. The EPA may promulgate more protective standards for THMs and bromate, which could cause Delta users to modify or abandon chlorine and ozone as major means of disinfection. Agencies have found that by injecting chemicals to lower the pH of water supplies, less chlorine or ozone is needed for disinfection, resulting in lower levels of these byproducts. Ultimately some municipalities may switch to pressure-driven membranes to meet more stringent drinking water quality standards.

Given that no one process is likely to be a panacea, or even adequate for treating all contaminants, water systems normally use a multiple-barrier approach to ensuring delivery of safe and healthy water. The first step is at-the-source protection of the watersheds themselves. The second step is water treatment: methods for treating water vary, though most agencies' processes include filtration followed by chemical disinfection. Once a water supply is treated, providers must ensure that its quality is protected as it traverses the distribution system. Finally, they must monitor the quality of their delivered product to detect any breakdowns in the process, and they must be prepared to respond immediately.

For this report, the combination of source protection and treatment is particularly germane. Under a rare regulatory exemption, the SFPUC is not presently required to filter its Tuolumne River supplies. Flows that are diverted downstream of Yosemite National Park, however, are likely to have higher concentrations of some contaminants, thus warranting filtration. In any case, Hetch Hetchy Valley will not be restored unless water quality is assured. The analysis conducted by EOA is intended to be merely the initial step in determining whatever additional treatments may be necessary for ensuring that water quality would not be diminished.

Summary of water-quality findings

This section summarizes EOA's analysis, highlighting findings of particular relevance to the question of how today's high level of water quality can be maintained if Hetch Hetchy Valley is restored. The discussion below represents Environmental Defense's characterization of EOA's findings. EOA's complete report is included as Appendix B.

CURRENT SFPUC WATER QUALITY

Under its current system, the SFPUC provides water—both to San Francisco residents and those of other Bay Area communities—that is obtained from several different sources. Most of the water (85 percent) in the overall SFPUC water-distribution system comes directly from Tuolumne River supplies held in Hetch Hetchy Reservoir. The other 15 percent comes from local reservoirs in Alameda County (across the bay) and in San Mateo County (along the San Francisco peninsula).

Water from Hetch Hetchy Reservoir comes from rain and snowmelt in the Sierra Nevada. Because there is little human development in the vicinity, the water from Hetch Hetchy is very clean. Monitoring results over the past decade show scant contamination of the water by minerals and chemicals, with aluminum being the only mineral found above monitoring equipment's detection limits. Water from Hetch Hetchy is also relatively low in bacteria, viruses, and protozoa that can cause human infections. Thus the SFPUC, like New York City, has obtained a rare exemption from the EPA that allows it to distribute water without sending it through a filtration plant; Hetch Hetchy water requires only the addition of disinfectants prior to distribution. It is possible, however, that the EPA will withdraw the current exemption, thus requiring the SFPUC to filter all of its supplies, even if Hetch Hetchy Valley is not restored.

WATER QUALITY UNDER VARIOUS RESTORATION ALTERNATIVES

Restoration of Hetch Hetchy Valley means that snowmelt waters of the Tuolumne River would no longer be captured and stored within Yosemite National Park. With sufficient flow, a portion of the river could be diverted directly to the Bay Area. At other times, water supplies would be diverted downstream. In effect, the loss of storage capacity within Hetch Hetchy Valley would result in a smaller proportion of San Francisco's water being diverted from the upper watershed, and more coming from downstream locations—not only along the Tuolumne (via Don Pedro Reservoir) but possibly from the Sacramento-San Joaquin Delta as well.

The question is: How would these changes alter the quality of the water that San Franciscans drink? To answer it, data from the different potential water sources was collected and analyzed. A comparison of water samples from these sources—Don Pedro, the Sacramento-San Joaquin Delta, and Hetch Hetchy Valley—indicated that they had minor differences in overall quality, although Hetch Hetchy samples did have lower levels of several contaminants. Most important, the Hetch Hetchy water was lower in bacterial contamination and slightly lower in levels of giardia and cryptosporidia.[5] Several chemical contaminants, including MTBE and barium, were higher in the Delta and Don Pedro Reservoir. The Delta water in particular was higher in arsenic and had a greater capacity to form trihalomethanes than either the Don Pedro or Hetch Hetchy raw waters, though it is known that agencies using Delta water are able to remove arsenic through filtration, as it is largely present as suspended particles.[6]

It should be noted that in all samples, the concentrations of chemical contaminants in the raw water were below state and federal drinking-water standards. Nonetheless, given the difficulty of removing many chemical contaminants with standard water filtration, and because few actual measurements were made of many of these contaminants—for example, only three measurements of MTBE were available from the Don Pedro system—the degree of contamination with specific chemical contaminants will need to be more fully characterized in the future.

To get a preliminary estimate, however, of how water quality would be affected by restoration of Hetch Hetchy Valley, EOA evaluated three alternatives based on the storage and conveyance options considered in Chapters 6 and 7.[7] These alternatives are characterized by varying amounts of water diverted from four principal locations, though in all cases the primary source is direct diversion from high in the Tuolumne River watershed (i.e., at Early Intake). Under the first alternative, additional water is captured downstream, primarily through diversion at or just downstream from Don Pedro Reservoir. Under the second, additional water is obtained from the Sacramento-San Joaquin Delta, while under the third, the additional water comes from Don Pedro Reservoir and additional storage capacity is available in an expanded Calaveras Reservoir. In each alternative, the Tuolumne River still provides the majority of San Francisco's water on an annual-average basis.

Using current monitoring results from each facility to predict the future quality of water blended from these sources, the first alternative reflects water-quality differences between the Hetch Hetchy and Don Pedro supplies—mainly, higher bacterial counts, slightly higher turbidity (a reflection of dissolved solids), higher total organic carbon (a predictor of elevated trihalomethanes and other disinfection byproducts) and MTBE. The second alternative, reflecting differences between Hetch Hetchy and Delta supplies, results again in higher bacterial counts, even higher turbidity, higher total organic carbon, and a slight increase in MTBE. In the last alternative, results are very similar to the first, as the increased Calaveras capacity only marginally influences the total mixture.

From a health standpoint, it is assumed that the anticipated increase in bacterial counts or turbidity will necessitate filtering water from the Don Pedro Reservoir and the Sacramento-San Joaquin Delta prior to consumption. The higher turbidity of the Delta water may require some extra steps (i.e., additional coagulation and sedimentation) to remove suspended solids so that the basic filtration and disinfection processes are effective at removing harmful bacteria. The higher levels of MTBE in the Don Pedro water may be more difficult to remove by filtration techniques, though the predicted levels of 1–2 micrograms/liter (mcg/L) are well below the California state standard of 13 mcg/L. It should also be noted that MTBE levels in water sources are expected to decline, as this chemical is no longer added to gasoline in California.

With the addition of existing filtration technologies, and based on available data, the water quality predicted to result from use of the Don Pedro or Sacramento-San Joaquin Delta source should be comparable, or even superior, to the quality of water from the current Hetch Hetchy source. In particular, filtration should reduce the presence of giardia and cryptosporidia to levels lower than those present in the current scheme. Further, filtration provides an additional layer of protection from water-contamination events. Table 8-1 provides a summary of anticipated water-treatment technologies that would be employed for each of the sources.

While it is difficult to predict the future capabilities of water-treatment technologies, significant advances are being made in this field. It is likely that

TABLE 8-1
Summary of treatment requirements and recommendations

	POINT OF DIVERSION					
Treatment process	**Hetch Hetchy**	**Early intake**	**Don Pedro**	**Calaveras**	**Peninsula**	**Sacramento-San Joaquin Delta**
Screening, coagulation, flocculation, sedimentation	◇	●	◆	◆	◆	◆
Basic filtration	◇	●	◆	◆	◆	◆
Enhanced treatment	◇	◇	◇	◇	◇	●
Disinfection	◆	◆	◆	◆	◆	◆
Additional treatment						○

◆ Currently required by law ◇ May be required in the future ● Recommended to satisfy health criteria ○ Recommended to match Hetch Hetchy water quality

TABLE 8-2
Estimates of unit water treatment costs

Water source	Unit cost of treatment ($/acre-foot)*	Reference
Hetch Hetchy Reservoir diversions	5	UC Davis, CALVIN Model, Appendix G[8]
Tuolumne downstream diversions	20	UC Davis, CALVIN Model, Appendix G
Local reservoirs	250	EBMUD Local Reservoir Estimate[9]
Delta supplies	220	UC Davis, CALVIN Model, Appendix G

*Excludes capital costs

more advanced water-filtration facilities—based, for example, on recent advances in membrane and magnetic ion-exchange methods—will become cost-effective in the near future and yield even cleaner water than is projected using existing technology.

All in all, the preliminary data analysis described in this section suggests that use of alternative sources such as the Don Pedro and Sacramento-San Joaquin Delta systems will deliver water whose quality is comparable to that of the existing Hetch Hetchy system, provided that water filtration is added. As noted earlier, however, more thorough monitoring and evaluation of the various water-source options is necessary before a plan for operating the SFPUC system without Hetch Hetchy Reservoir can be adopted.

Water-treatment costs

EOA's preliminary findings enable us to estimate the costs of additional treatment for the restoration alternatives considered in this report, which assumes that the SFPUC would filter all of its supplies. Schlumberger Water Services estimated that to increase the capacity of the Sunol Treatment Plant by 160 million gallons per day (beyond the SFPUC's planned 80 million gallons per day expansion) would incur a capital cost of $134.4 million to $288 million (See Appendix A).

Table 8-2 provides estimates of the unit costs of water treatment. They are integrated with capital costs and other operating expenses in Chapter 10.

In short:

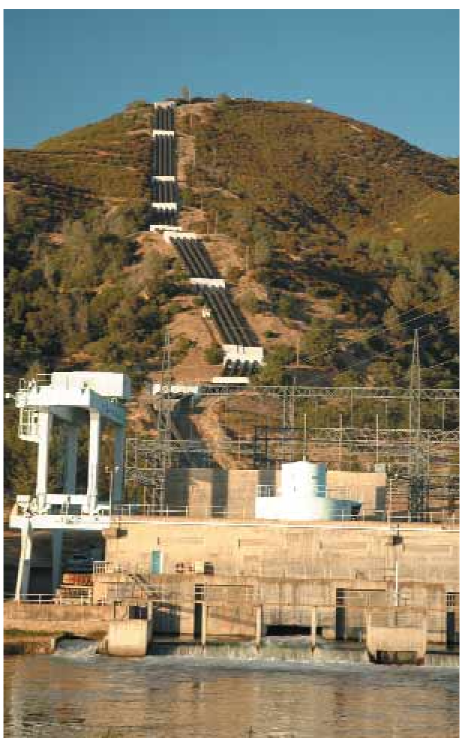
- Diversions from Hetch Hetchy Reservoir are very inexpensive to treat because they are not filtered. These supplies are currently treated with a chloramine process: chlorine is added to the water at Tesla Portal and ammonia is added in Sunol Valley.
- Diverting further downstream on the Tuolumne River would also be relatively inexpensive to treat. Chemical treatment would change little, but the water would be filtered.
- Treating water from the Delta and local reservoirs would be considerably more expensive because increases in organic matter, turbidity and other constituents need to be addressed. A variety of techniques, including chlorine dioxide and carbon dioxide injection, are currently used to remove bromide from Delta supplies. Treating water in local reservoirs often requires advanced treatment, including additional coagulation, flocculation and sedimentation, to cope with algal blooms. However, given the infrequent use of these sources, the total expected cost of treatment might not be significant.

CHAPTER 9

Impact of restoration on hydropower production and revenues

Restoring Hetch Hetchy Valley will reduce power generation on the Tuolumne River, with a consequent loss of revenue from energy sales as well as a need to replace the forgone energy with some combination of new generating capacity and demand-side resources.

The loss of generation at the Tuolumne River hydroelectric facilities of the San Francisco Public Utilities Commission (SFPUC) would be as much as 690 million KWh, or 40 percent of average annual energy production. With modifications to the SFPUC's facilities, however, the average annual loss could be as low as 339 million KWh/year. Depending on whether water is diverted downstream or upstream of Don Pedro dam, output at the Don Pedro powerhouse—owned by the Turlock and Modesto Irrigation Districts (TID and MID)—could increase by up to 54 million KWh per year (+10 percent) or decline by 8 million KWh (–1.4 percent).



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Moccasin Powerhouse is one of three hydroelectric plants the SFPUC operates on the Tuolumne River. If Hetch Hetchy Valley is restored, Moccasin would still be able to produce electricity when the river is flowing. On average, annual output would decline by about 30 percent.

Several options are available to replace the lost energy, including increased investments in energy efficiency, expansion of dynamic pricing programs, and the development of new renewable or natural-gas-fired power plants. Regarding the latter, a survey of recent forecasts indicates that a reasonable estimate of the levelized cost of energy from new renewable or gas-fired baseload plants is $55/MWh. Demand-side options, meanwhile, offer cost-effective means of reducing the energy and capacity needs currently met by the SFPUC's hydropower facilities. All together, replacement energy costs for the SFPUC facilities would range from $18.6 to $38.0 million per year, and monetary values for impacts on Don Pedro's output would range from an annual loss of $440,000 to a gain of nearly $3 million.

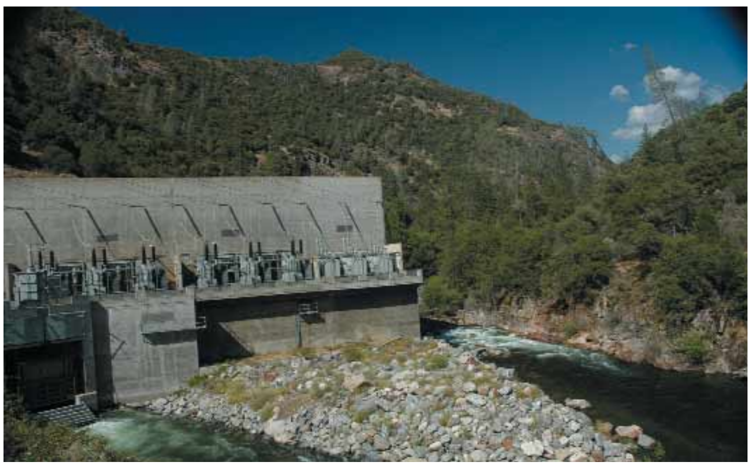
Impact of restoration on hydropower operations

Restoration would reduce power production at the SFPUC's Kirkwood and Moccasin powerhouses, while generation at TID and MID's Don Pedro powerhouse could either increase or decrease slightly. Generation at the SFPUC's Holm Powerhouse would not be affected by restoration because that facility operates with water from Cherry and Eleanor Reservoirs.

The greatest impact of decommissioning O'Shaughnessy Dam would occur at Kirkwood. Some of Kirkwood's 118 MW of capacity could be retained by constructing a small diversion dam at the site of O'Shaughnessy Dam and capturing run-of-river flows in the Canyon Tunnel. This would require modification, or perhaps replacement, of the existing tunnel that now conveys water to the Kirkwood Powerhouse.[1] The loss of storage behind O'Shaughnessy Dam would also reduce production at Moccasin because generation would be limited to those times of year when there is sufficient natural flow in the Tuolumne River. Hydropower production at TID and MID's Don Pedro powerhouse could either rise or fall slightly, depending on where San Francisco diverts and stores water under the different restoration alternatives.

The TREWSSIM model that simulated water storage and deliveries under alternative restoration scenarios was also used to develop estimates of energy impacts. The analysis assumed that whether or not Hetch Hetchy Valley is restored, the SFPUC would continue to operate the system on a "water first" basis, even if that meant forgoing opportunities to increase energy revenues by optimizing hydroelectric operations. During the energy shortages of 2000–2001, for instance, when the SFPUC had to spend millions on expensive spot-market power purchases, it adhered to this operating principle.[2] The analysis also assumed that Kirkwood remains a base-load facility while San Francisco uses Moccasin to generate peaking power when needed. But the analysis ignored ancillary service revenues because SFPUC staff stated that its plants do not participate in those markets.[3]

The modeling results vary only slightly across the restoration alternatives that were considered. What matters most is whether Kirkwood can be operated as a run-of-river plant. A small diversion structure near the current O'Shaughnessy Dam could retain much of the existing hydropower generation while simultaneously permitting restoration of Hetch Hetchy Valley. Output at Moccasin Powerhouse is not affected by Kirkwood's availability.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Top: The SFPUC's Kirkwood Powerhouse generates electricity using water that flows from Hetch Hetchy Reservoir via the Canyon Tunnel. With modifications to the tunnel, Kirkwood could continue to produce nearly two thirds of its current output under a restoration scenario. Otherwise Kirkwood would become inoperable and have to be retired. Bottom: The Dion R. Holm Powerhouse, which produces about 40 percent of the SFPUC system's annual hydropower output, would be unaffected by restoration of Hetch Hetchy Valley. It generates energy using water from two of the Tuolumne's tributaries, Cherry and Eleanor Creeks.

IMPACT OF RESTORATION ON SFPUC ENERGY PRODUCTION

Table 9-1 summarizes the impact of restoration on average annual hydropower production at each of the SFPUC's powerhouses for two different scenarios, as well as the Base Case

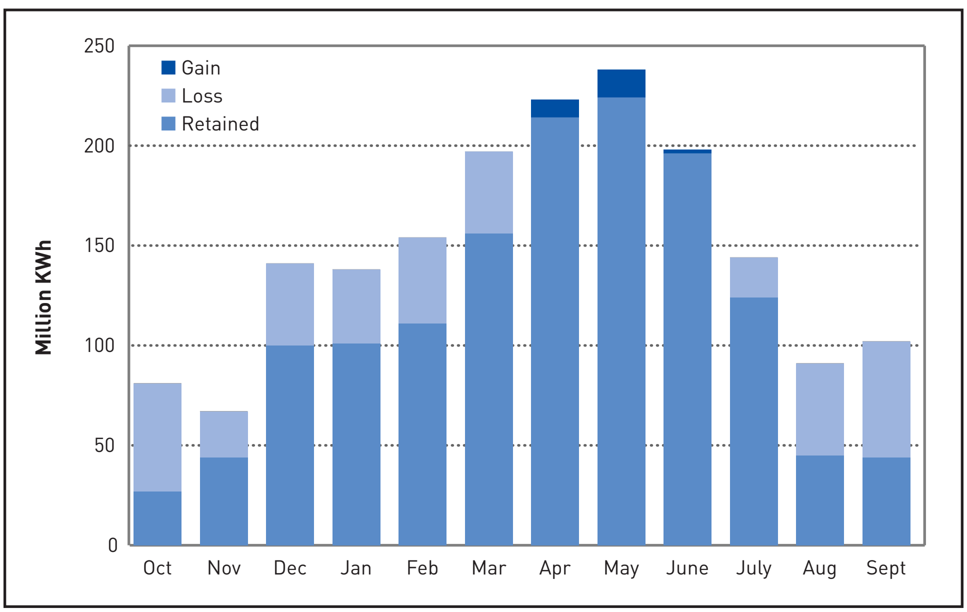
TABLE 9-1
Average annual energy impacts (million KWh)

	Kirkwood	Moccasin	Holm	Total	Change million KWh	Change Percent
Base case	549	427	749	1,725	NA	NA
Restored: Kirkwood run-of-river	352	286	749	1,387	–339	–19.6%
Restored: Kirkwood unavailable	—	286	749	1,035	–690	–40.0%

(which represents production with O'Shaughnessy Dam still in place). Hydropower impacts of the alternative scenarios were calculated by comparing modeled generation under each alternative to modeled generation in the Base Case. Average annual generation is estimated to decline by 339 million KWh/year if a diversion dam replaces O'Shaughnessy and both Kirkwood and Moccasin operate as run-of-river facilities. If the Canyon Tunnel is not modified to permit continued operation of Kirkwood Powerhouse, the average annual loss is 690 million KWh. Even in this case, however, San Francisco would still retain more than half of the average annual production from its Tuolumne River hydroelectric facilities.

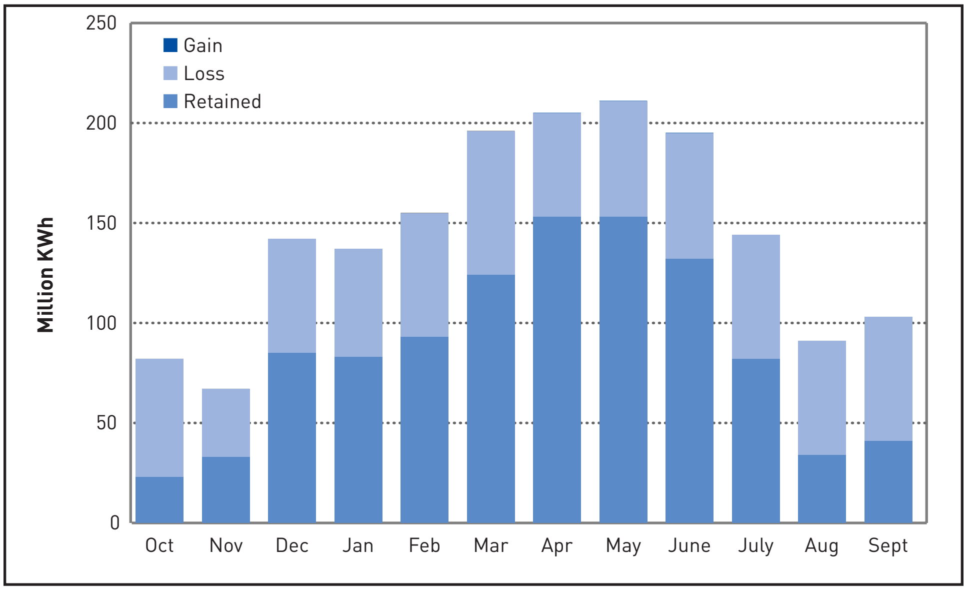
Impacts on hydropower production would vary throughout the year. Figure 9-1 illustrates the changes in simulated average monthly generation for the entire SFPUC system if Kirkwood powerhouse can be operated as a run-of-river facility.[4] Without the dam to impound spring runoff, less electricity would be produced in most months.

FIGURE 9-1
SFPUC system: average monthly generation
Kirkwood operated as run-of-river



If Kirkwood Powerhouse can be operated as a run-of-river facility, restoring Hetch Hetchy Valley would reduce the SFPUC's annual hydropower production by about 20 percent on average. Generation would be lower in most months, but would actually increase during the spring runoff.

FIGURE 9-2
SFPUC system: average monthly generation Kirkwood unavailable



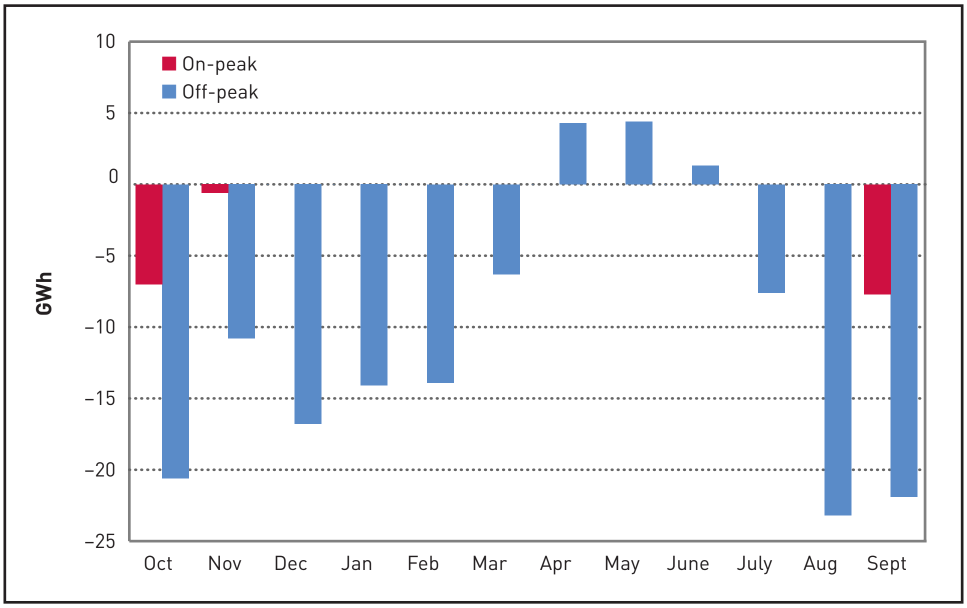
If the Canyon Tunnel cannot be modified to permit continued operation of Kirkwood Powerhouse, restoration would lower the SFPUC's annual hydropower production by about 40 percent on average. Generation losses would be fairly evenly distributed, with percentage impacts greatest in late summer and early fall.

The greatest reductions would occur in September and October, while average generation would actually increase slightly in April and May. Figure 9-2 shows how lost generation would be distributed throughout the year if Kirkwood were completely unavailable. In absolute terms, generation losses would be fairly evenly distributed, with percentage impacts greatest in late summer and early fall.

An important consideration is how the lost energy production would be distributed between on-peak and off-peak periods. Power is more valuable during on-peak periods, especially in the summer months. This analysis focuses on Moccasin powerhouse, in that water-supply operations and physical limitations constrain Kirkwood powerhouse to base-load operation.[5] The availability of the regulating Priest Reservoir permits San Francisco to shape generation at Moccasin. The analysis assumes that San Francisco reserves all available flows for peaking, with off-peak energy produced only in months when flows exceed the amount needed to operate Moccasin at capacity (during peak hours). Restoration would not affect this facility, but it would constrain San Francisco to generate at times when the river is flowing.

Figure 9-3 shows how the monthly losses in generation at Moccasin might be distributed between peak and off-peak periods. In most months, run-of-river flows would still be sufficient to run Moccasin at capacity during all peak hours, but significant on-peak reductions would occur in September and October. The cost of replacing on-peak energy during these months is likely to be much higher than replacing off-peak or base-load generation at other times of year; however, these losses account for no more than 5 percent of the change in annual output and would

FIGURE 9-3
Projected change in average monthly generation Moccasin operated as run-of-river



Without Hetch Hetchy Reservoir, the SFPUC would still be able to use Moccasin Powerhouse to generate valuable on-peak energy at most times of year. Lost on-peak energy production in September and October would be costly to replace, but accounts for less than 5 percent of the total reduction in output for the SFPUC system.

not significantly increase annual replacement-energy costs. Off-peak generation would be lower in most months, but would increase in April-June. Actual operations could follow a different decision rule than is assumed in this analysis, resulting in a more modest reduction in production of on-peak energy.

IMPACT OF RESTORATION ON SFPUC'S DEPENDABLE CAPACITY

Like water resource planners, power system operators are particularly concerned with the ability of generating resources to meet users' needs during critical periods. For hydroelectric resources this means determining the rate at which a power plant can produce electricity during system peak periods (i.e., the handful of hours during late summer afternoons when customer demand is highest). Table 9-2, based on TREWSSIM simulations, shows how the average monthly capacity of Kirkwood and Moccasin are reduced as a result of restoring Hetch Hetchy Valley. On average, Moccasin is able to operate at its full 100 MW capacity during on-peak hours in most months. Significant reductions occur in September and October, requiring the SFPUC to obtain replacement capacity of up to 64 MW. If Kirkwood can operate as a run-of-river facility, average capacity losses range up to 44 MW, with gains realized during the spring runoff. If Kirkwood is completely unavailable, average capacity losses peak at 89 MW in June, tapering off to 31 MW by November.

Because hydropower production varies with the availability of water to generate energy, system planners pay particular attention to how much energy can be produced during peak periods in dry years. One approach to assessing a hydropower facility's dependable capacity, in fact, is based on its production during the most adverse hydrologic conditions encountered over the period of record. For central California, this is August and September of 1977, the driest year of the 20th century.

Table 9-3 summarizes results from the TREWSSIM model that compare the availability of Moccasin and Kirkwood under 1977 hydrology, with and without O'Shaughnessy Dam. For each powerhouse, the table documents its availability for peaking, the number of hours it could operate at its full capacity during the month, and the rate at which it could produce a steady stream of baseload energy. Table 9-3 shows that for Moccasin, capacity impacts would be greater in the driest years than on

TABLE 9-2
Average available generating capacity by month (MW)

	Moccasin (peak hours*)			Kirkwood unavailable (baseload operation**)			Kirkwood run-of-river (baseload operation**)		
	Base	Restored	Change	Base	Restored	Change	Base	Restored	Change
October	100	42	–58	43	—	–43	43	6	–37
November	100	95	–5	31	—	–31	31	15	–16
December	100	100	—	54	—	–54	54	22	–33
January	100	100	—	54	—	–54	54	24	–30
February	100	100	—	65	—	–65	65	25	–40
March	100	100	—	87	—	–87	87	43	–44
April	100	100	—	77	—	–77	77	83	+6
May	100	100	—	85	—	–85	85	98	+12
June	100	100	—	89	—	–89	89	88	–1
July	100	100	—	75	—	–75	75	57	–18
August	100	100	—	46	—	–46	46	15	–32
September	100	36	–64	44	—	–44	44	5	–38

Notes: *Peaking capability, 12:00–6:00 PM weekdays. **Baseload capability, round-the-clock operation.

TABLE 9-3
Impact of restoration of SFPUC hydropower capacity under adverse hydrology

	(1) Total monthly energy production (million KWh)		(2) Average hourly rate of energy production (MW)		(3) Hours available to operate at rated capacity	
Moccasin Powerhouse rated capacity: 100 MW	**August**	**September**	**August**	**September**	**August**	**September**
Base	31.7	32.6	42.6	43.8	306.8	314.8
Restored	1.4	1.0	1.9	1.3	13.8	9.7
Kirkwood Powerhouse rated capacity: 118 MW	**August**	**September**	**August**	**September**	**August**	**September**
Base	29.8	30.7	40.1	41.2	288.5	296.7
Restored: Kirkwood operates as ROR	1.2	0.8	1.6	1.1	11.7	8.2
Restored: Without Kirkwood	0.0	0.0	0.0	0.0	0.0	0.0

(2) = (1)/number of hours in month
(3) = (1)/nameplate generating capacity of powerhouse

average. For Kirkwood, dry-year capacity losses are comparable to average impacts. With O'Shaughnessy Dam in place, even with 1977 hydrology, Moccasin would be available to operate over 300 hours in each of those months, more than enough to assure its availability on all weekday afternoons. Without O'Shaughnessy Dam's storage capacity, Moccasin could not be depended on for peaking operation under adverse hydrologic conditions. Transforming Moccasin into a run-of-river facility would thus eliminate the powerhouse's entire rated capacity of 100 MW under the most adverse hydrology.

Table 9-3 shows that *even with O'Shaughnessy Dam in place*, Kirkwood can only reliably produce at a rate of about 40 MW under 1977 hydrologic conditions. This amount is about a third of its installed capacity. Under run-of-river operation without O'Shaughnessy Dam, Kirkwood's dependable capacity of 40 MW is almost completely lost. A review of historical operating data shows that Kirkwood actually produced only half the modeled energy generation during August and September 1977, although it has managed to run at close to 40 MW in other critically dry years. Thus the loss of dry-year capacity at Kirkwood could be as low as 20 MW.

IMPACT ON DON PEDRO HYDROPOWER OPERATIONS

Restoration of Hetch Hetchy Valley could either increase or decrease hydropower production at TID and MID's Don Pedro powerhouse. Two key factors are how much, and where, Tuolumne water is diverted to the Bay Area. Table 9-4 summarizes their impacts, under current and projected future demand, by comparing the base case with two different alternatives for restoration of the valley. Construction of an intertie with the SFPUC's aqueduct at or upstream of Don Pedro Reservoir, with the current level of demand, would lower flows through the Districts' powerhouse relative to the base case, reducing average annual hydropower production; under the projected 2030 level of demand, flow and production would grow modestly. In contrast, downstream diversions would increase flows and generation non-trivially for both periods. No matter where the intertie is located, an increase in Tuolumne River diversions to meet projected growth in demand would reduce flows through Don Pedro powerhouse and lead to a decrease in hydropower production relative to output at the current level of diversions. This is because more water would be diverted above the intertie at Early Intake.

To assign a monetary value to the projected changes in Don Pedro's hydroelectric output, it is important to know the time of year when they occur and whether the Districts' ability to generate during peak hours is affected. With extensive storage and a regulating

TABLE 9-4
Impact of restoration on average annual Don Pedro generation

	Current demand			Projected 2030 demand		
	Annual generation	Change from base		Annual generation	Change from base	
Alternative	**(million KWh)**	**(million KWh)**	**Percent**	**(million KWh)**	**(million KWh)**	**Percent**
Base	574	NA	NA	544	NA	NA
Downstream diversion	605	+31	+5.4%	598	+54	+9.9%
Upstream diversion	566	–8	–1.4%	549	+5	+0.9%

dam downstream, Don Pedro is configured to take advantage of opportunities to produce on-peak energy, however many considerations govern operation of the dam and its hydroelectric facilities. TREWSSIM monthly modeling results indicate that the relatively small reduction in hydropower production projected for an upstream intertie would be evenly spread throughout the year, so losses in on-peak energy revenues would likely be minimal. In contrast, if the intertie were built downstream of the dam, increases in hydropower production would be concentrated in late summer months when power is most valuable. The financial benefit to TID and MID would be even greater if the incremental water could be used to augment energy production during the peak afternoon period.

Options for replacing forgone Hetch Hetchy energy and capacity

In addition to lowering San Francisco's power-sales revenues, a reduction in hydroelectric generation from the Tuolumne would also oblige the SFPUC to find alternate ways of meeting users' energy requirements. This burden would be shared by the Turlock and Modesto Irrigation Districts, which currently purchase a significant portion of the Hetch Hetchy-derived energy. Even after their current contracts with San Francisco expire, TID and MID will retain their Raker Act entitlements to continue making such purchases for their pumping and municipal loads.

This section describes potential approaches for replacing the forgone hydroelectric generation, taking into account the stated objectives of San Francisco and the Districts for meeting their customers' future energy needs (see discussion in Chapter 4). While a complete assessment of the available alternatives is beyond the scope of this study—it would require detailed historical and projected data on energy generation and consumption and on purchase patterns involving all of San Francisco's and the Districts' electricity sources—the discussion that follows is based on publicly available statistics and is intended to provide an overview of the feasibility, environmental performance and relative cost of potential sources of replacement energy.

Four options are considered: increased investments in energy conservation, expanded use of dynamic pricing, and construction of new renewable or natural-gas fired-power plants. For generation alternatives, the analysis focuses on new baseload facilities. California's demand for electricity is currently forecast to grow at 2.2 percent per year over the next decade[6] and new generating capacity may be needed as soon as 2006,[7] well before restoration of Hetch Hetchy Valley is likely to begin. Therefore it is reasonable to assume that the forgone Hetch Hetchy energy and capacity would be replaced with electricity from new facilities. And because most of the lost hydroelectric production is either baseload or off-peak energy, it is also reasonable to assume that power will be replaced by new baseload units. In addition, because some on-peak energy may be needed to replace output from Moccasin powerhouse in late summer, the cost of energy from new gas-fired peaker plants is also discussed briefly.

ENERGY EFFICIENCY

The need to replace some, or perhaps all, of the lost Hetch Hetchy energy could be eliminated by investing in energy efficiency, especially as the untapped energy efficiency potential in California remains vast. Based on analyses conducted by its own staff and a leading consulting firm, the California Energy Commission (CEC) has concluded that increasing public investment in energy efficiency over the next 10 years may yield some major payoffs. The state could cut its annual energy use by as much as 30,000 million KWh while shaving up to 10 percent (5,900 MW) off statewide system peak demand—*and at no net cost.*[8] That is, the net present value of avoided future electricity bills[9] exceeds the up-front expense of installation and equipment. To put it simply, up to a point it costs less to install energy-saving equipment than to build and run new power plants.

Actually, the CEC's estimate of California's untapped conservation potential is itself conservative. It is based exclusively on existing technologies that can be retrofit into existing buildings, and it does not take into account behavioral changes, the impacts of emerging technologies, or integrated redesign of buildings' energy-using systems. In any case, the CEC has recommended in its *2003 Integrated Energy Policy Report* that the state double its existing public funding for energy-efficiency and conservation programs in order to cut at least an additional 1,700 MW from peak demand and 6,000 million KWh from energy use by 2008.[10]

Calculating exactly how much of this potential could be realized in San Francisco and the Districts is beyond the scope of this study. Such an analysis would need to take into account local climate conditions, existing penetration of energy-efficiency technologies, and a host of other factors. However, a "ballpark estimate" may be obtained by scaling San Francisco's and the Districts' share of statewide energy use to the estimated statewide savings. This calculation yields 1,137 million KWh per year in potential energy savings by 2008[11]—an amount that significantly exceeds the potential loss of 339-690 million KWh/year of Hetch Hetchy energy derived in this study. While practical constraints make it unlikely that the replacement of Hetch Hetchy power could be entirely eliminated by new investments in energy efficiency, the calculation at least shows that increased energy efficiency could certainly offset some of the need to build new power plants, and at lower cost.

Moreover, investments in energy efficiency need not be confined to San Francisco or to TID and MID's service territories in order that demand for Hetch Hetchy energy be displaced. The same intensively interconnected grid that permits the City and the Districts to draw electricity from all over the West also permits them, in principle, to benefit from energy savings realized elsewhere. Thus the SFPUC, TID and MID could cost-effectively sponsor investments in energy efficiency in surrounding communities as one additional way to "replace" Hetch Hetchy power. Investing locally, however, may prove more attractive, as it would create jobs within the community; numerous workers, both skilled and unskilled, would be needed to retrofit buildings, install energy controls, replace inefficient old appliances, and service heating and cooling equipment.

DYNAMIC PRICING

Another demand-side resource with significant untapped potential in California is dynamic pricing. The CEC and the California Public Utilities Commission (CPUC) are currently working to develop programs in which electricity customers—large commercial facilities, most likely—would face electricity prices that vary with market conditions. Rates would be highest during peak periods (when power is the scarcest), giving program participants the incentive to cut their energy use at that time. Unlike current interruptible tariffs, in which a small number of very large customers drastically cut their energy use when supplies run short, dynamic pricing encourages a large number of customers to make smaller, less-disruptive cutbacks.

TABLE 9-5
Recent proposals for renewable generation in the Western U.S.

	California (million KWh/year)	Neighboring states (million KWh/year)	Other WECC* (million KWh/year)	Total (million KWh/year)
Wind	17,021	24,893	5,270	47,184
Geothermal	6,961	2,249	867	10,077
Biomass and Biogas	2,146	175		2,321
Solar CSP	263	110		373
Total (rounded)	**26,390**	**27,430**	**6,135**	**59,955**

Source: California Energy Commission, *Public Interest Energy Strategies Report,* December 2003. Table 5-3, p. 94.
*Western Electricity Coordinating Council

Dynamic pricing is essentially a peaking resource, displacing the need for new peaker plants that run infrequently (i.e., only a few hundred hours per year during high-load periods). It can be an important component in plans to replace the loss in on-peak energy and dependable capacity that would result if Hetch Hetchy Valley is restored. According to CEC forecasts of the resources required to meet California's future energy demands, dynamic pricing can pare five percent from system peak demand statewide.[12] Applying this estimate to recent peak load statistics for San Francisco, TID and MID—along with the same caveats noted in the preceding section—suggests that as much as 95 MW of peak energy use could be displaced with dynamic pricing in these regions.[13]

FPL ENERGY, LLC

Opened in 2003, FPL Energy's 162-MW High Winds Energy Center in Solano County will provide electricity to the cities of Sacramento, Pasadena, Anaheim, Glendale, Azusa, Colton and others.

RENEWABLE ENERGY

Renewable energy—wind, geothermal and solar—is another viable option for replacing the hydroelectric generation foregone with the restoration of Hetch Hetchy Valley. These alternatives already account for nearly a tenth of California's annual energy production, and they are poised to gain a bigger share as the state's investor-owned utilities comply with a new law that requires them to meet 20 percent of their customers' needs with renewable energy by 2017. While no generation technology is completely free of adverse environmental impacts, wind and solar facilities produce no emissions and geothermal plants emit mainly steam.[14] An important concern about wind energy in particular is the deaths of birds, especially raptors, that collide with turbine blades, but advances in turbine design and improved siting practices have significantly reduced avian mortality at new wind facilities.

California and interconnected Western states have abundant renewable-energy potential. As shown in Table 9-5, a recent CEC survey of proposals for new renewable generation in this region found that the potential for California alone is 26,390 million KWh/year. Meanwhile, new renewable facilities capable of producing 27,430 million KWh/year have been proposed in adjacent states.

Wind energy dominates the renewable resources in the West, accounting for nearly two-thirds of California's in-state renewable potential and for four-fifths throughout the region. Not all of the proposed projects will be built, as some require extensions of transmission lines that could prove prohibitively expensive. But wind-energy developers believe that several thousand megawatts of economical wind potential remains to be developed in California and neighboring states. Even older wind farms, such as the Altamont complex seen from I-580 near Livermore, may provide additional output as the original wind turbines are replaced with much more efficient new models. This approach has the advantage of making use of existing transmission lines and reducing the disruptions associated with developing new facilities.[15]

San Francisco would need to "firm up" the capacity of purchased wind energy, much as it now does with the output from its Hetch Hetchy facilities, in order to reliably satisfy demand. Just as water must be available to generate hydropower, the wind must be blowing in order for wind turbines to spin and generate electricity. Wind energy is an intermittent resource, meaning that a given facility's availability cannot be predicted in advance, as is the case with fossil-fired plants and hydropower units with storage. However, California's best wind-energy sites are blessed with fairly dependable winds that tend to blow hardest during periods of peak electricity demand. For example, Northern California's wind facilities are situated so as to exploit the strong afternoon winds that develop when intense heat in the Central Valley sucks cooler coastal air through gaps in the Coast Ranges.

MOSCONE CENTER

Installation of rooftop solar panels, efficient lighting, and energy-management systems at San Francisco's Moscone Center are projected to cut the building's annual electricity use by over 5 million KWh, yielding net savings of over $200,000 per year.

Purchasing renewable energy presents limited opportunities for local investments and job creation. This is because the availability of renewable-energy sources, such as strong winds and geothermal activity, determines the specific location of facilities. Solar power, too, is most economical in places like the Central Valley, where there are many hours of sunshine (especially during peak demand periods). San Francisco's legendary summer fog, not to mention its urban density, limit the attractiveness of developing large-scale solar-energy facilities within the City, but a recently passed $100-million bond initiative provides financing for installation of solar panels, as well as energy-efficiency technologies and wind turbines, on public buildings.

NATURAL GAS

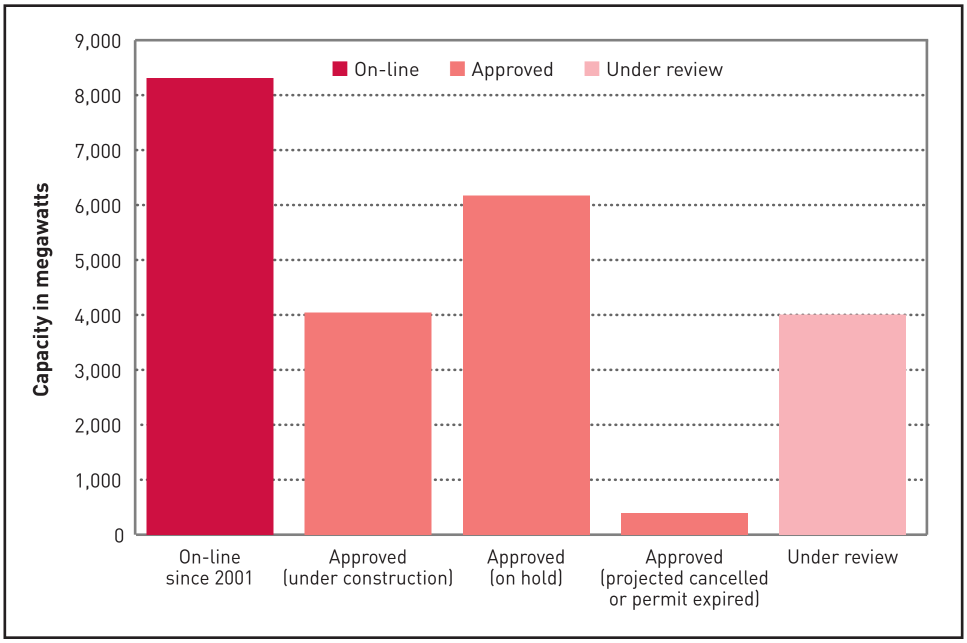
Within California, highly efficient combined-cycle natural-gas-fired power plants have accounted for much of the new baseload generating capacity added in recent years. This technology, moreover, is forecast to remain a major incremental source of energy over the next decade. The combination of state-of-the-art pollution controls and the federal Clean Air Act's requirement that all emissions of the conventional pollutants (e.g., nitrogen oxides and sulfur oxides) from new stationary sources be offset with corresponding reductions from other sources means that new gas-fired plants do not increase net emissions in an air basin. Ambient concentration of pollutants may be higher in the immediate vicinity of the plant,[16] however, and new gas-fired generation does emit greenhouse gases, though at a much lower rate than older plants. If all of the foregone Hetch Hetchy hydropower were replaced with electricity generated at a new combined-cycle gas-turbine power plant, the increase in CO_2 emissions would be 138,000-305,000 tons per year.[17] The upper bound represents less than 0.1 percent of statewide CO_2 emissions.[18]

A number of options are available to offset any increase in CO_2 emissions that results from replacing Hetch Hetchy hydropower with gas-fired energy. One approach is investing in energy efficiency projects that reduce energy used by buildings or fuel burned by vehicles. Alternatively, CO_2 emissions may be offset by paying landowners to follow management practices that increase the amount of carbon stored in forests and agricultural lands. The latter approach, known as sequestration, removes carbon from the atmosphere. A nearby example is the Oregon Climate Trust, which is employing both approaches to offset CO_2 emissions from new power plants in that state. Projects it has undertaken include the following: building energy efficiency, transportation efficiency, cogeneration, distributed generation, and permanent forest sequestration. The average cost of offsets in the Climate Trust's portfolio is $3/ton.[19]

Just 40-90 MW of combined-cycle gas-fired generating capacity could replace the energy that would be lost at Hetch Hetchy.[20] The new baseload gas-fired power plants now being built in California typically have a capacity of 500 MW, so from 8-18 percent of the capacity of just one of these new plants is all that would be needed. Meanwhile, California has added over 8000 MW of new generating capacity since the summer of 2001, most of it gas-fired, and more is in the pipeline (Figure 9-4 summarizes recent activity in construction, permit applications and proposed projects for new power plants in California). Thus the amount of Hetch Hetchy energy that needs to be replaced is dwarfed by

FIGURE 9-4

Summary of California power plant additions and permitting: 2001–2003



The amount of generating capacity needed to replace lost hydropower from the SFPUC's Tuolumne River powerhouses is dwarfed by recent and planned additions to California's fleet of power plants. California has added over 8000 MW of new capacity since summer 2001 and more is in development. Just 40–90 MW of new gas-fired capacity would be needed to replace the Hetch Hetchy energy.

Source: California Energy Commission

the quantities of new generation now being developed in the state.

Although new conservation investments and dynamic-pricing programs may reduce peak demand, or at least limit its growth, at times it may be necessary to replace on-peak energy that would have been produced at Moccasin powerhouse. Simple-cycle gas-fired peaker plants have recently been the primary source of incremental supplies of on-peak energy in California. A typical peaker plant has a capacity of 100 MW, enough to replace the peaking capability that would be lost at Moccasin during late-summer months.

A major disadvantage of gas-fired power plants is the exposure to financial risk from fluctuating natural-gas prices, though owners can reduce their risk by entering long-term gas-purchase contracts or using financial instruments such as forward and futures contracts.

Cost of replacement energy

This section surveys recently published estimates of the cost of energy both from new and existing power plants. While forecasts of spot-market energy costs are considered first, a more likely scenario is that San Francisco and the Districts would either build or purchase replacement power from a new central-station power plant.

Levelized cost estimates, which spread a power plant's initial capital cost out over its entire economic life and smooth trends and fluctuations in projected fuel costs, are presented for combined-cycle natural-gas-fired plants and new renewable facilities. These estimates enable comparisons between the two types of technologies, which have differing proportions of capital and operating costs. Results may be succinctly summarized: the 20-year levelized cost of energy both from gas and renewable facilities range from $50 to $60/MWh, supporting a value of $55/MWh for the average annual cost of replacing lost Hetch Hetchy power.

COST OF PURCHASING SPOT-MARKET ENERGY

One way to estimate the cost of replacing lost Hetch Hetchy energy is to examine projected market prices for electricity. Recent forecasts from a variety of sources are summarized in Table 9-6, which shows that short-term forecasts range from about $35 to $40/MWh. Looking farther into the future, projected electricity prices depend on assumptions about the trajectory of future natural gas prices. Base-case projections for 2012 and 2013, when replacement power might actually start to be used, range from $50 to $55/MWh. Because forecasts of spot-market prices are very sensitive to underlying assumptions about future natural gas prices, they are included (when available) with Table 9-6.

Basic elements of the forecasts presented in Table 9-6 are described below:

- For the Trinity River SEIS/EIR (Supplemental Environmental Impact Statement/Environmental Impact Report), Henwood Energy Services developed hourly forecasts of market-clearing prices in Northern California in 2005 using its proprietary MARKETSYM model. These estimates were derived from Henwood's spring 2003 forecast of Western electricity markets. Purchased by utilities, power plant developers, banks and rating agencies, Henwood's forecasts are widely accepted among energy-market participants.
- In testimony submitted to the CPUC, Pacific Gas and Electric Company (PG&E) has recently developed

TABLE 9-6
Projected spot electricity and natural gas prices ($2003)

Forecast	Average annual electricity spot-market price ($/MWh)	Underlying natural gas price forecast ($/MMBtu)
Henwood Energy Services (2004)		
Dry conditions—2005	37.75	NA
Average conditions—2005	36.13	NA
Wet conditions—2005	34.84	NA
Marcus (2003)		
Projected 2005	39.00	4.50
Projected 2012	50.00	5.54
Pacific Gas and Electric Company (2004)		
High gas-price forecast—2013	73.37	7.76
Base gas-price forecast—2013	55.35	5.54
Low gas-price forecast—2013	42.57	3.32

Sources:

(1) Henwood Energy Services. February 5, 2004. *Power Impact Analysis for the Trinity SEIR/EIS Central Valley Project Phase 2 Report*, Appendix B.

(2) Marcus, William. March 2003. *Clean and Affordable Power: How Los Angeles Can Reach 20% Renewables without Raising Rates.* Report prepared for the Environment California Research and Policy Center and the Center for Energy Efficiency and Renewable Technologies.

(3) Pacific Gas and Electric Company. January 9, 2003. *Testimony Supporting PG&E's Application to Replace the Steam Generators in Units 1 and 2 of the Diablo Canyon Power Plant.* Testimony submitted to the California Public Utilities Commission in A.04-01-009.

estimates of the cost of replacing energy from its Diablo Canyon nuclear generating station. PG&E uses its own natural gas price forecast as a basis for determining future market-clearing electricity prices from Henwood's MARKETSYM model. The prices in PG&E's base analysis are somewhat higher than those currently being used by other analysts.

- Marcus adjusts the CEC's most recent electricity-market clearing-price forecast by increasing the underlying natural gas prices, thereby reflecting recent market developments.

Spot-market prices are typically higher during on-peak than in off-peak hours, and this is especially true in California during the summer months, when system-wide electricity demand is most intense. However, the price forecasts presented in Table 9-6 are annual averages that combine projections both for on-peak and off-peak periods.

Current forecasts of spot-market electricity prices provide a lower bound on the likely cost of replacing Hetch Hetchy energy because they reflect only operating costs and do not take into account the capital cost of constructing new power plants. But energy markets are widely expected to tighten in future years, necessitating the construction of new capacity.

COST OF ENERGY FROM A NEW NATURAL-GAS-FIRED POWER PLANT

A more conservative way to estimate of the cost of replacing Hetch Hetchy energy is to assume that it is all purchased from a newly built combined-cycle natural-gas-fired baseload power plant, and two recent analyses have in fact projected the levelized costs of such a facility. A 2003 CEC study estimated that the levelized cost of electricity from a new 500-MW plant in northern California would be $52/MWh over 20 years.[21] Marcus then adjusted the CEC's estimate using an updated natural gas price forecast, obtaining a 20-year levelized cost of $53/MWh in southern California.[22] The CEC study acknowledges that the cost of building and operating a particular project could be higher than its generic estimate, as a result of site-specific costs such as emissions-offset purchases and the establishment of connections to gas pipelines and the transmission grid.

Higher gas-price forecasts increase the levelized energy-cost estimates of gas-fired power plants. In testimony submitted to the CPUC, the Pacific Gas and Electric Company estimated the cost of replacing energy from its Diablo Canyon nuclear facility with energy from a new gas-fired power plant. PG&E's analysis used the CEC cost model mentioned above but substituted a higher forecast of future gas prices. Extrapolating back to 2005 from PG&E's base-case projection for 2013–2024 yields a levelized cost of $57/MWh.[23]

The long-run incremental cost of gas-fired on-peak energy is considerably more expensive than baseload power. This is because peaker plants are less efficient than baseload facilities and their capital costs must be recovered over only a few hundred operating hours per year. The CEC estimates that the 20-year levelized cost of energy from a simple-cycle peaker plant would be $157/MWh.[24]

COST OF ENERGY FROM A NEW RENEWABLE-ENERGY FACILITY

Today, wind energy is the most inexpensive renewable alternative to natural gas. After surveying the available data (including the results of recent bid solicitations by the California Power Authority and San Diego Gas and Electric for contracts ranging up to

20 years' duration), Marcus concludes that "a significant number of renewable projects can be readily developed by private-merchant plant developers at costs of $55/MWh or less." His analysis of a wind project being developed by the Los Angeles Department of Water and Power, for example, yields a 30-year levelized cost of $52/MWh.[25]

Marcus' estimates are consistent with the CEC's analysis of the comparative cost of energy from various central-station generating technologies. The CEC study pegs the 30-year levelized cost for electricity from a 100-MW wind farm at $49.30/MWh, though it notes that actual installed costs in any given location may be higher, depending on the expenses incurred in acquiring land and connecting new wind developments to the transmission grid.[26]

While most analysts predict increasing natural gas prices over time, the cost of renewable generating technologies is generally expected to fall. This has certainly occurred in recent years as these technologies' market penetration has increased, and a recent CEC report projects further reductions. The cost of wind energy is forecast to fall nearly 40 percent over the next 15 years, reaching $30/MWh by 2017.[27] At least partially offsetting this projected trend is a possible side-effect of the increased demand for wind energy caused by the California legislature's adoption of a renewable portfolio standard (RPS). This law, which requires that the state's investor-owned utilities purchase 20 percent of their electricity from renewable sources by 2017, will accelerate development of the best sites while leaving higher-cost sites to the market's latecomers.

ANNUAL COST OF REPLACEMENT ENERGY

Based on this review of available data, a reasonable estimate of the long-term costs of replacing forgone Hetch Hetchy hydropower production is $55/MWh. For the SFPUC facilities, the annual cost of replacement energy would be $18.6 to $38.0 million. This range reflects current projections of the cost of energy from new gas-fired baseload facilities and recent bids to supply renewable energy in California.

While volatile natural-gas prices may drive up the cost of gas-fired generation in the future, the cost of energy from wind facilities is forecast to decline over time. Therefore much of the forgone generation could be replaced with wind power, with gas-fired generation firming up capacity. Increased investments in energy efficiency and expanded dynamic-pricing programs may also displace energy and capacity needs at a cost less than that of energy from new generating facilities. While on-peak energy can cost significantly more to replace than off-peak or baseload power, it appears that San Francisco would retain much of its ability to generate during on-peak periods. Losses in on-peak energy production represent no more than 1.5 percent of the overall reduction in SFPUC hydropower output and would not have a significant impact on annual replacement-energy costs.

Depending on where San Francisco diverts water, restoration may either increase or decrease generation at Don Pedro. If generation decreases (upstream diversion), it is reasonable to assume that TID and MID's per-unit replacement cost would equal the estimate ($55/MWh) developed above. With a downstream diversion, the Districts could actually realize increased power-sales revenues. Given that the increased output would occur during the high-demand late-summer months, $55/MWh is a lower bound on the increased revenue to the Districts. Applying this figure to the projected changes in generation at Don Pedro (see Table 9-4), implies that the value of increased or decreased hydropower generation at Don Pedro varies between a loss of $440,000 and a gain of $3 million per year.

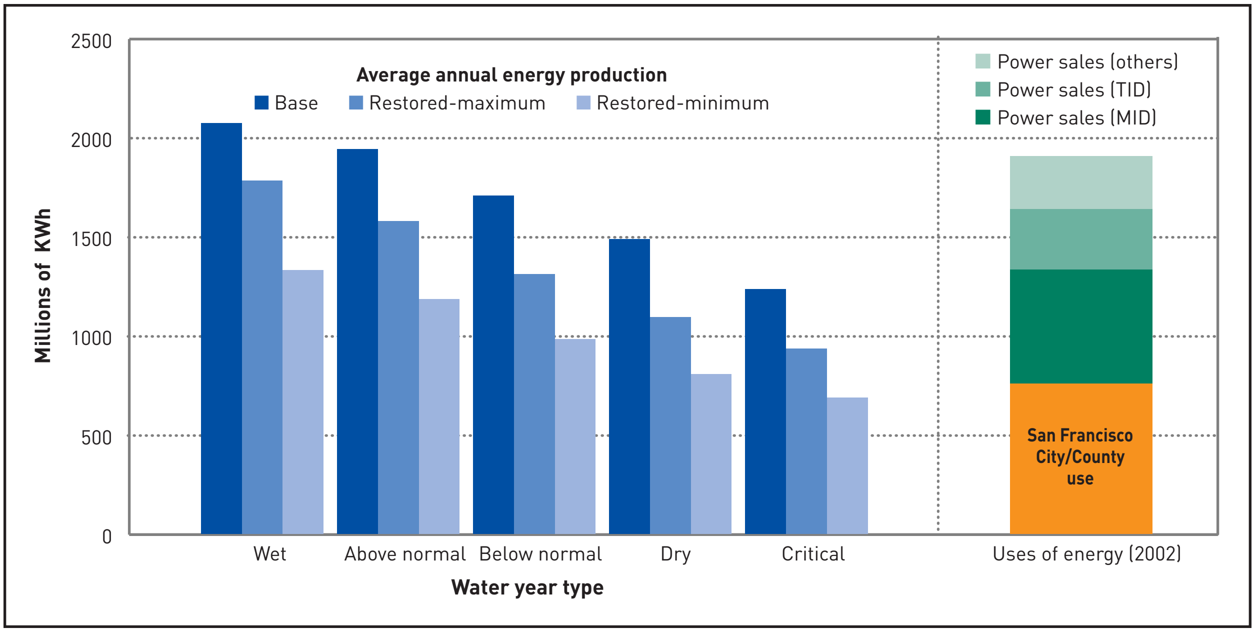
Financial impacts on San Francisco and the Districts

It is important to note that the replacement-energy values developed in the preceding section represent social values—the worth of lost generation resources to *all* parties that use Hetch Hetchy energy. For individual stakeholders, however, the relevant question is what share of this social value they will bear. San Francisco's Tuolumne powerhouses have been a source of inexpensive energy for the City, the Districts, and other public entities that have bought Hetch Hetchy power over the years. For the Districts, low-cost hydropower produced at Don Pedro powerhouse has sheltered them from having to purchase more expensive energy. For San Francisco, Hetch Hetchy energy has also been a source of power-sales revenues, especially after the City entered its firm power-sales contracts with the Districts in 1987. Those contracts became money-losers for the City during the price spikes of 2000–01, and San Francisco has moved to terminate them early. Even after the current contracts are terminated, however, San Francisco will retain its Raker Act obligation to sell the Districts surplus power at cost-of-service rates.

As shown in Figure 9-5, with the valley restored the SFPUC's Tuolumne River powerhouses would still provide enough energy to meet San Francisco's current public-sector needs on an annual basis in all but the driest years. In the latter half of the year, the City would need to increase the amount of energy it already purchases to augment hydroelectric out-

FIGURE 9-5

Projected annual generation vs. 2002 uses of Hetch Hetchy hydropower



Hetch Hetchy hydropower accounts for a tiny share of California's electricity supply, but is a valuable energy source for San Francisco and the Turlock and Modesto Irrigation Districts. If the valley is restored, the SFPUC's powerhouses would still provide enough energy to supply the City's current needs in all but the driest years. The City would have to buy additional power at times, and less energy would be available to sell to the Districts and others. Renewable energy and investments in energy efficiency can cost-effectively fill the gap without increasing air pollution.

Source: US DOE Form EIA-861 and EIA-412

put. In dry years, the City might also need to purchase energy at other times. Less surplus energy would be available for resale to the Districts and others.

For San Francisco, the fiscal impacts of restoration would thus be an increase in the cost of purchasing power to meet its own needs and a loss in power-sales revenues. But although the $55/MWh replacement-power cost estimate developed in the preceding section fairly reflects the cost of purchasing additional energy, it significantly overstates the per-unit revenue losses to San Francisco of forgone energy sales. Given the Raker Act requires San Francisco to sell surplus power to TID and MID at below-market cost-of-service rates, the Districts would shoulder most of the financial burden of decreased power sales as they faced the prospect of replacing Hetch Hetchy energy at market rates.

Recommendations for further analysis

This chapter has provided an initial planning-level estimate of the annual cost of replacing Hetch Hetchy's energy, based on modeled hydropower production and current projections of long-term electricity costs. Further analysis, using more detailed data, is needed in order to determine the optimal mix of alternative supply- and demand-side resources.

A more complete investigation would need to consider seasonal and daily patterns of energy use, taking into account anticipated growth. It would also need to assess existing generation resources, including power-purchase contracts. The analysis should carefully consider how energy losses would be divided between off-peak and on-peak periods, given the significant seasonal and daily price swings that occur in electricity markets. Opportunities to modify hydropower operations or facilities to increase the proportion of on-peak energy, while meeting all water-supply needs, should also be weighed. Localized assessments of energy-efficiency opportunities and of the potential to displace peak energy use through dynamic pricing should be completed as well.

CHAPTER 10

Water and power replacement costs

Earlier chapters have presented different ways of replacing the water supply, water-quality and hydropower services currently provided by Hetch Hetchy Reservoir and O'Shaughnessy Dam, along with estimates of the replacements' capital and operating costs. This chapter integrates those estimates and gives a range of discounted present values for the total cost. The analysis does not fully account for all costs of restoration, nor does it attempt to address the value of a restored Hetch Hetchy Valley in Yosemite National Park. It simply focuses on the most challenging and costly components of restoration—water and power—while acknowledging that the costs of many of their elements must be refined and that further analysis will therefore be needed (recommendations for further study are presented in Chapter 12).

The chapter begins with an overview of the cost components developed earlier in this report. Some of these costs are presented as "snapshots"—single estimates of the projected value. Others, such as capital costs for new infrastructure, are presented as ranges.

Total water and power replacement cost estimates are given for a variety of restoration scenarios that account for critical uncertainties and posit different levels of future SFPUC water deliveries to the Bay Area. Each of these alternatives includes an intertie to the lower Tuolumne River and an expanded water-treatment plant, as both are likely to be necessary elements of any restoration plan. The alternatives do differ, however, in the ways in which they replace existing water storage, given that multiple workable options are available.

A discussion of the choice of discount rate and study period then follows, and the chapter concludes by presenting a range of total water and power replacement costs under each alternative.

Costs of restoration components

Table 10-1 presents annual and capital costs of each component, along with brief explanatory notes on key assumptions. These factors are further discussed below.

HYDROPOWER

If Hetch Hetchy Valley were restored, hydropower generation at the SFPUC's Kirkwood and Moccasin powerhouses would be reduced. If the Canyon Tunnel were modified, much of the generation at Kirkwood would be retained (without modification, Kirkwood is assumed to be unusable). In either case, generation at Moccasin would be diminished but not eliminated, while generation at Holm powerhouse would not be expected to change significantly.

The chief determinants of replacement-energy costs—a power market analysis and the results of simulations using the Environmental Defense's TREWSSIM model—are discussed in Chapter 9. No estimate was made for modifying the Canyon Tunnel.

Power generation could also increase or decrease slightly at the Turlock and Modesto Irrigation Districts' Don Pedro Powerhouse, depending on where the SFPUC diverts water under a restoration alternative. Estimates of changes in average annual generation at Don Pedro and the cost of replacement energy are presented in Chapter 9, but are not included in the cost calculations shown here.

WATER SUPPLY

Water-supply costs include the construction of an intertie to the lower

Tuolumne River, the rebuilding (and possible expansion) of the Calaveras Reservoir, development of infrastructure for a groundwater bank, and the purchase of water from willing sellers in critically dry years. Schlumberger Water Services provided estimates of the capital, O&M (operation and maintenance) and energy costs for the water supply components (see Appendix A).

Lower Tuolumne intertie All restoration scenarios assume that an intertie from the SFPUC aqueduct to the lower

TABLE 10-1
Component Costs of Restoration Alternatives ($M 2004)

Cost category	Low	High	Explanatory notes
Hydropower ($M/year)	18	38	The high cost assumes no generation at Kirkwood. The low cost assumes that run-of-river generation is possible if the Canyon Tunnel is modified.
Don Pedro intertie			
Capital ($M)	25	54	Based on estimate of $30M, plus 20 percent for engineering, legal and administrative costs, with a standard range of uncertainty of –30 percent to +50 percent
Operating ($M/year)	3	3	Includes O&M (operation and maintenance) and energy costs
Calaveras rebuilt at current size ($M)	19	41	Based on estimate of $23M, plus 20 percent for engineering, legal and administrative costs, with a standard range of uncertainty of –30 percent to +50 percent
Expanded Calaveras			
Dam capital cost ($M)	76	162	Based on estimate of $90M, plus 20 percent for engineering, legal and administrative costs, with a standard range of uncertainty of -30 percent to +50 percent
Pump station capital ($M)	37	78	Based on estimate of $43M, plus 20 percent for engineering, legal and administrative costs, with a standard range of uncertainty of -30 percent to +50 percent
Operating ($M/year)	2	3	Includes O&M and energy costs
Groundwater			
Capital ($M)	100	215	Based on estimate of $119M, plus 20 percent for engineering, legal and administrative costs, with a standard range of uncertainty of –30 percent to +50 percent
Operating ($M/year)	2	2	Includes O&M and energy costs
Expanded water-treatment plant			
Capital ($M)	202	432	Based on estimate of $240M, plus 20 percent for engineering, legal and administrative costs, with a standard range of uncertainty of –30 percent to +50 percent
Operating ($M/year)	14	27	Local reservoir and Delta supplies require more expensive treatment

Tuolumne River will be built. This intertie would be used mainly in the summer and fall.

Calaveras Reservoir Calaveras Reservoir would be rebuilt under all of the alternatives. In the existing-conditions alternative, as well as groundwater and transfer-replacement alternatives at the SFPUC's current level of demand, the reservoir would be rebuilt at its current size (97,000 acre-feet). Under an alternative that dedicates expansion of Calaveras to replacing storage lost in the restoration of Hetch Hetchy Valley, as well as for all SFPUC alternatives in 2030, Calaveras Reservoir would be expanded to 420,000 acre-feet—the maximum size that the SFPUC is considering. Natural inflow from Calaveras Creek alone is not considered sufficient to justify an expansion to 420,000 acre-feet; a pump station and pipelines, to move Tuolumne River or other supplies into Calaveras, would be constructed as well. Because of differences in elevation, significant energy costs would be incurred in pumping supplies into Calaveras, an operational strategy that keeps the reservoir full but minimizes pumping would be warranted.

Groundwater banking (Tuolumne Basin) The groundwater bank is assumed to hold a maximum storage of 400,000 acre-feet, and maximum recharge and extraction rates are 200 cubic feet per second (cfs). The groundwater alternative also assumes additional conveyance to allow in-lieu recharge of up to 386 cfs. This additional groundwater would normally be pumped only in critically dry years. The capital and operating costs for groundwater banking in the Tuolumne Basin are based on estimates provided by Schlumberger Water Services.

Transfers (Tuolumne Basin) A conservative rate of $500 per acre-foot (substantially higher than other transfer agreements currently in place) is assumed in the alternatives that employ dry-year transfers to supplement supply. No fixed costs are assumed for water transfers. The SFPUC's water supply needs are likely to occur only in dry years. A water-transfer option agreement, similar to that between Metropolitan Water District and the Palo Verde Irrigation District, under which Metropolitan pays a significant one-time fee for the right to purchase specific amounts as needed, might be optimal for the SFPUC.

Transfers and groundwater (Delta supplies) The cost of using Delta diversions to ensure that demand is fully met in dry years is also assumed to be $500 per acre-foot, independent of whether the additional supply is made available through a groundwater exchange agreement or through a transfer. Delta supplies are more expensive to treat than Tuolumne supplies, resulting in slightly higher costs in years when the additional supply is used.

WATER TREATMENT

Under the existing-conditions alternative, there is no change in water-treatment capability. Under the future-conditions alternative, the SFPUC would expand its Sunol Water Treatment Plant by 80 million gallons per day (MGD). Under all restoration alternatives, the Sunol Water Treatment Plant would be expanded by 240 MGD. The plant would also be expanded if the SFPUC were either to lose its filtering exemption or elect, on its own, to filter all of its water. This uncertainty is addressed in the scenario analysis.

The TREWSSIM model was used to determine the amounts of water

BANCROFT LIBRARY

Shortly after the stock market crash of 1929, Bank of America founder A.P. Giannini (front right) purchased $4,000,000 in Hetch Hetchy bonds to help assure the project's completion.

treated under the various alternatives. Schlumberger Water Services provided estimates of the capital and O&M costs of new water-treatment facilities (see Appendix A). The unit costs for water treatment from various sources, as discussed in Chapter 8, were largely obtained from input data for UC Davis' CALVIN model; these values vary widely, depending on the quality of the source. The unit cost of filtering and treating Don Pedro supplies is assumed to be only $20 per acre-foot. Treating supplies released from local reservoirs or Delta sources are assumed to cost more than 10 times as much.

Scenarios for evaluating replacement water and power costs

Many factors influence the cost of implementing the water-supply alternatives considered in this report, so it is difficult to accurately predict which alternative will ultimately be the most feasible or how much its constituent elements will cost. But for the purposes of this initial planning-level analysis, some critical uncertainties—those most likely to have the largest impact on total costs—are identified as follows:

- Whether demand remains at the current level or rises to the projected 2030 level.
- Whether Kirkwood power plant would be usable for generating power when the Tuolumne River's flow is sufficient.
- Whether capital costs for infrastructure are in the "high" range or "low" range.
- Whether the SFPUC would filter all of its supplies, even if Hetch Hetchy Valley were not restored.

These uncertainties are addressed in the scenarios we examined, as summarized in Table 10-2.

TABLE 10-2
Summary of scenarios evaluated

Scenario	Level of demand	Capital costs	San Francisco maintains filtration exemption	Hydropower loss at Kirkwood
1	Current	High	Yes	Full
2	Current	High	Yes	Partial
3	Current	High	No	Full
4	Current	High	No	Partial
5	Current	Low	Yes	Full
6	Current	Low	Yes	Partial
7	Current	Low	No	Full
8	Current	Low	No	Partial
1A	Projected*	High	Yes	Full
2A	Projected*	High	Yes	Partial
3A	Projected*	High	No	Full
4A	Projected*	High	No	Partial
5A	Projected*	Low	Yes	Full
6A	Projected*	Low	Yes	Partial
7A	Projected*	Low	No	Full
8A	Projected*	Low	No	Partial

*As described in Chapter 7, the SFPUC's Water Supply Master Plan projects that its demand will increase 17% from the current level of 260 MGD to 303 MGD (or 339,000 acre-feet per year) by 2030.

Study period and discount rate

All component cost estimates were converted into net present values, using a real discount rate of 5 percent. This number falls in the middle of the range of discount rates (2–7 percent) recommended by the U.S. Office of Management and Budget, General Accounting Office and Congressional Budget Office for use in cost-benefit analysis of government projects and policies.[1] The literature on discounting provides rationales for using a lower discount rate in this type of project: some economists have argued for using a very low discount rate for projects with very long term or remote impacts in order to place more weight on benefits or costs to be realized by future generations. "Hyperbolic discounting" in fact goes one step further by applying progressively lower discount rates to increasingly distant project impacts. Lower discount rates are also considered appropriate when projects will be financed by taxes or user fees paid primarily by consumers. Higher discount rates are usually recommended for projects that displace private-sector investment, an unlikely prospect for restoring Hetch Hetchy Valley.[2]

Subsequent analyses should explore the sensitivity of the costs of restoration to variations in the discount rate, especially values at the low end of the assumed range. These sensitivity analyses would be most informative, in the context of a more thorough study that includes estimates of benefits as well as costs. Using a lower discount rate would increase the present value of total project costs by increasing the contribution of future annual expenses. The impact of a lower discount rate on the present worth of benefits will be even greater as all of the benefits of restoration would be realized as perpetual streams.

The time horizon used in this study is 50 years, beginning in 2004. Fifty years, a relatively lengthy time horizon for a study of this type, was chosen to provide a reasonable estimate of the service lives of new facilities that would need to be built to provide replacement water and energy, as well as to capture an outside estimate for existing hydropower and treatment facilities.

Although restoration efforts would not begin for several years, costs of labor and materials are expressed in current dollars. No effort has been made to project these costs into dollars of future years, when expenses might actually be incurred. By contrast, wholesale electricity costs, used to estimate pumping and replacement-energy costs, are forecast to rise gradually over time from today's values. Consistent with standard practice in cost-benefit analysis, all values are expressed in real terms and exclude the effects of general inflation.

Total cost estimates

Table 10-3 presents the total costs of replacing the water and power provided by Hetch Hetchy Reservoir, at the SFPUC's current delivery objective of 260 MGD, under the scenarios discussed above and the alternatives presented in Chapter 7.

TABLE 10-3
Total water and power replacement cost estimates under current SFPUC delivery objective

	Water supply alternative—millions of dollars (2004)			
Scenario	**Surface storage replacement**	**Groundwater exchange replacement (Tuolumne source)**	**Transfer replacement (Tuolumne source)**	**Transfer or groundwater replacement (Delta source)**
1 High capital costs Continued filtration exemption Full hydropower loss at Kirkwood	1,648	1,559	1,389	1,426
2 High capital costs Continued filtration exemption Partial hydropower loss at Kirkwood	1,296	1,206	1,036	1,074
3 High capital costs Discontinued filtration exemption Full hydropower loss at Kirkwood	1,150	1,060	890	928
4 High capital costs Discontinued filtration exemption Partial hydropower loss at Kirkwood	798	708	538	576
5 Low capital costs Continued filtration exemption Full hydropower loss at Kirkwood	1,283	1,185	1,130	1,167
6 Low capital costs Continued filtration exemption Partial hydropower loss at Kirkwood	931	833	777	815
7 Low capital costs Discontinued filtration exemption Full hydropower loss at Kirkwood	1,016	917	862	900
8 Low capital costs Discontinued filtration exemption Partial hydropower loss at Kirkwood	663	565	510	547

TABLE 10-4
Total water and power replacement cost estimates under projected 2030 SFPUC delivery objective

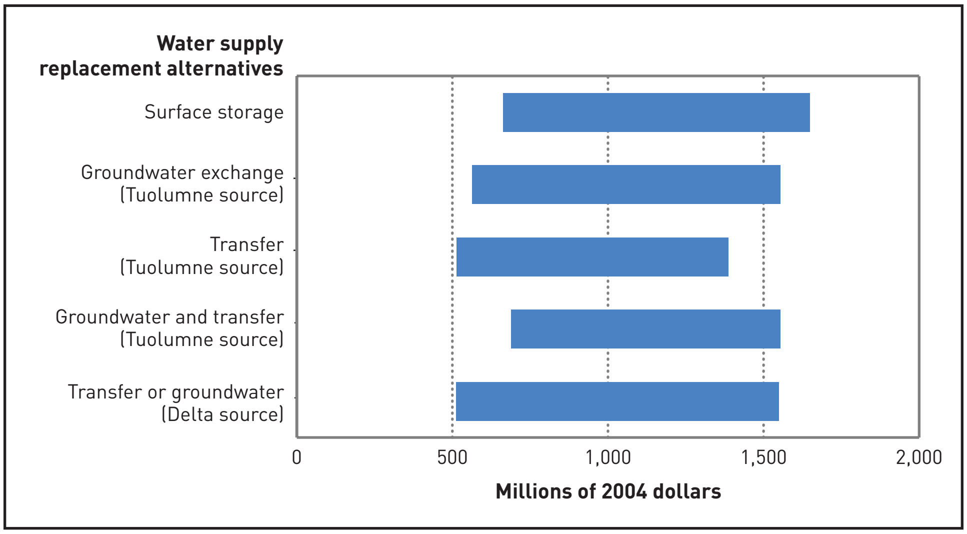
Scenario	Water supply alternative—millions of dollars (2004)			
	Groundwater exchange replacement (Tuolumne source)	Transfer replacement (Tuolumne source)	Groundwater and transfer replacement (Tuolumne source)	Groundwater or transfer replacement (Delta source)
1A High capital costs Continued filtration exemption Full hydropower loss at Kirkwood	1,510	1,327	1,544	1,370
2A High capital costs Continued filtration exemption Partial hydropower loss at Kirkwood	1,157	975	1,191	1,017
3A High capital costs Discontinued filtration exemption Full hydropower loss at Kirkwood	1,148	965	1,182	1,008
4A High capital costs Discontinued filtration exemption Partial hydropower loss at Kirkwood	795	613	829	655
5A Low capital costs Continued filtration exemption Full hydropower loss at Kirkwood	1,213	1,145	1,247	1,188
6A Low capital costs Continued filtration exemption Partial hydropower loss at Kirkwood	861	793	895	835
7A Low capital costs Discontinued filtration exemption Full hydropower loss at Kirkwood	1,005	937	1,039	979
8A Low capital costs Discontinued filtration exemption Partial hydropower loss at Kirkwood	653	584	686	627

Table 10-4 offers comparable cost estimates for 303 MGD (the SFPUC's projected level of demand in 2030). Figure 10-1 provides a graphical illustration of the range of estimated costs under each alternative.

The above values are estimates of the costs of water and power replacement only. They do not include the expenses of removing O'Shaughnessy Dam, restoring Hetch Hetchy Valley or building facilities to accommodate the visitors from across the United States and throughout the world who would be attracted both by the valley and the unprecedented restoration process.

This analysis focuses on total water and power replacement costs to society at large, and does not address how they would be distributed among stakeholders. As restoration alternatives are further explored and refined in a public process, a variety of funding sources—including the federal and state governments, communities that receive Tuolumne River water and hydropower, user fees paid by park visitors, and philanthropic donations—should be explored.

FIGURE 10-1
Estimated range of water and power replacement costs



Our study focuses on the most challenging and expensive components of restoration—the costs of replacing the water and power services Hetch Hetchy Reservoir provides. Cost estimates vary depending on where replacement water supplies are diverted and stored. Costs also depend on key uncertainties, including the future level of demand, whether San Francisco can continue to avoid filtering its entire water supply, the capital costs of restoration components, and how much restoration reduces hydropower generation. Devising an equitable approach to sharing these costs will be an essential element in developing a plan to finance the valley's restoration.

CHAPTER 11

Legal status and institutional considerations

Restoring Hetch Hetchy Valley raises a host of complicated legal and institutional issues. While their complete analysis is beyond the scope of this report, Environmental Defense retained Stuart L. Somach of Somach, Simmons and Dunn to prepare a memorandum addressing several important questions related to San Francisco's water- and power-supply operations. This memorandum is included in this report as Appendix C, and its findings provide much of the background for the material that appears in this chapter.

The chapter opens with a general description of San Francisco's current rights to divert water from the Tuolumne River, to generate power from the river, and to store the water for later use. The discussion then turns to a survey of significant legal and institutional considerations associated with the potential restoration of Hetch Hetchy Valley. The chapter concludes with a brief section noting that changes in federal and state laws are likely to be required for the valley to be restored.

In a matter as complex as a restoration of this scale would be, a first-level analysis of the current status and potential alterations of San Francisco's water and power system cannot address all the relevant questions. Complexity, however, should not be confused with impossibility. Given the will and the means to accomplish the goal, this initial analysis has found no legal obstacle sufficiently formidable to block consideration of Hetch Hetchy Valley's restoration.

San Francisco's current rights to water, storage and power

WATER LAW AT THE TURN OF THE LAST CENTURY

The original thirteen colonies of the United States, largely incorporating the common law of England, allocated water by granting riparian rights that allowed landowners adjacent to streams (i.e., "riparians") to divert and store water freely, so long as other riparian landowners were not harmed as a result. Rarely did conflicts develop, as water was plentiful in all of the eastern states.

Riparian-rights systems, however, were insufficient to encourage development of the American west's largely arid environment. As a result, an appropriative-rights system was established in the region, including California, whereby a prospective water user staked its claims to divert water from a stream—in many cases for use in a different watershed—and so long as that claim was deemed "first in time" it became "first in right." Provided that the claimant made continuous beneficial use of the water claimed, this right remained senior to any claim made by subsequent would-be appropriators and, eventually, by riparians as well. This system was codified in California in 1914. Water users asserting rights acquired before 1914 must base their claims on notices filed with county authorities or, as explained in Appendix C, on assertions of prescription against other users in the watershed. Claims made after 1914 have required permits and licenses issued by a state agency, now the State Water Resources Control Board.

SAN FRANCISCO'S WATER RIGHTS

Beginning in 1901, as noted in greater detail in Appendix C, San Francisco asserted claims to the diversion of water from the Tuolumne River and its tributaries, not only for itself but also for others who eventually became its partners in that water's use. By the time San Francisco asserted these claims, however, others who were desirous of the Tuolumne River's bounty, most notably the Turlock Irrigation District (TID) and the Modesto Irrigation District (MID), had already staked their own very large claims to its flows.

When San Francisco sought leave from the federal government to build a dam within Yosemite National Park's Hetch Hetchy Valley—in order to store water, divert it to San Francisco and environs, and generate hydroelectric power—the Districts protested, citing their senior rights.

Lengthy negotiations ensued, the fruits of which were incorporated in the Raker Act.[1] Summarizing a complex tale, TID's and MID's senior state-law-based water-diversion rights were ratified by Congress in the Raker Act (principally sponsored by and named after John Raker, a Congressman from the San Joaquin Valley town of Manteca). The Act confirmed that San Francisco's rights to divert water from the Tuolumne River were junior to specified quantities of flow required to be released downstream for the benefit of the Districts, in accordance with their prior rights; and, as Appendix C explains, the Act contained an ongoing duty not to export more water from the river than was "necessary for its beneficial use for domestic and other municipal purposes."

Subject to these caveats, however, the Raker Act did grant San Francisco the necessary right-of-way and other authorities needed for it to proceed with the construction of O'Shaughnessy Dam and related facilities.

Since then, there have been many changes in California and federal water law. Among them are stated preferences in state law for domestic and municipal uses of water; judicially developed application of the public-trust doctrine; and a series of cases, interpreting Article X, section 2 of the California Constitution, that established there should be no waste of water or unreasonable uses or diversions of water (see *The public-trust doctrine,* page 96).

The domestic- and municipal-preference legislation tends to strengthen San Francisco's Tuolumne rights, to the potential detriment at least of TID's and MID's agricultural diversions from the Tuolumne, should significant drought limit supplies on the river. Potential applications of the public-trust and unreasonable-use-and-diversion doctrines tend to weaken San Francisco's rights to divert from the Tuolumne, at least upstream, should circumstances arise that provide the City with alternative water supplies downstream that would simultaneously provide multiple benefits to public-trust resources.

Aside from its Tuolumne rights, San Francisco also holds rights to divert and store water in local watersheds in the Bay Area, notably Alameda and Calaveras Creeks. Although no other consumptive water users currently have significant competing claims to these local resources, these rights too are subject to the potential application of modern environmentally oriented water law designed to assure appropriate consideration of public-trust values and prevent the unreasonable use or diversion of the state's waters.

SAN FRANCISCO'S STORAGE RIGHTS

In a recent proposal to increase San Francisco's "rental fee" for its use of Hetch Hetchy Valley to store water and generate power, the Bush Administration highlighted anew the City's perennially controversial status as an occupant and user of land in a national park.

When it originally acquired the right to store water behind O'Shaughnessy

The public-trust doctrine

Dating from classical times, the "public-trust doctrine" evolved through English common law to provide that navigable waters and the lands beneath them are held by the state in trust for the people. It provides a legal basis for states to limit uses of these resources that conflict with the broader public interest.

The public-trust doctrine's best-known application to a water-rights controversy occurred in the context of Los Angeles' diversion of water from eastern Sierra streams feeding Mono Lake. The California Supreme Court in *National Audubon Society v. Superior Court*,[2] held that the public trust could restrict Los Angeles' Mono Basin diversions, even though Los Angeles had acquired water rights to the feeder streams many decades earlier. Pursuant to this decision, the State Water Resources Control Board (SWRCB) later limited Los Angeles' right to divert stream flows, an action aimed at balancing the environmental interests of Mono Lake and Basin with the competing water-use needs of Los Angeles.

Article X, section 2 of the California Constitution has had many applications in environmental and conservation controversies. Among them, the case of *Environmental Defense Fund (EDF) vs. East Bay Municipal Utility District* (EBMUD)[3] may be the longest-lasting. Originally filed in 1972, the litigation has gone through two hearings in the California Supreme Court, a remand from the U.S. Supreme Court, an SWRCB proceeding, and a trial in Alameda County Superior Court. These proceedings ultimately led EBMUD to change the proposed location of an additional planned water diversion to a point on the Sacramento River below its confluence with the American River. EDF had originally asserted, among other things, that because an upstream diversion would be damaging to environmental values in the lower American River, it constituted an unreasonable use and diversion of water.

MONO LAKE COMMITTEE

Mono Lake was central to one of the best-known applications of the public-trust doctrine. In 1983 the California Supreme Court held that the public trust could restrict Los Angeles' Mono Basin diversions to protect this important natural resource.

Dam, San Francisco's most formidable opponents were no doubt TID and MID (with whom San Francisco was then forced to seek an accommodation). But its most vocal opponents were members of the then-nascent conservation movement, broadly distributed throughout the United States and led locally by John Muir, noted naturalist and founder of the Sierra Club. Conservationists' protests on behalf of the sanctity of Yosemite National Park and of the splendors of its "twin valley" were turned back, however, in order to supply San Francisco—still recovering from the great earthquake of 1906—with water and power and to provide a public alternative to the growing might of Pacific Gas and Electric Co. (the rapidly expanding private-utility "monopoly").

Battled over through successive national administrations, Republican and Democratic alike, as well as multiple Congresses increasingly enmeshed in the public-private controversies of the day, San Francisco finally persuaded Congress to pass the Raker Act, and President Woodrow Wilson to sign it into law, in 1913. This act is the fundamental federal authorization for San Francisco to store a significant share of its water supply in Yosemite National Park.

Although potentially subject to changing federal and state water and environmental laws, San Francisco's water-storage rights in Yosemite are indefinite in duration. Absent actions that it might take in contravention of provisions of the Raker Act or Congressional legislation amending (as by increasing the rental fee) or terminating its rights, San Francisco's leasehold effectively continues in perpetuity.

As has been explored in greater detail earlier in this report, however, San Francisco's water storage at Hetch Hetchy is but a minor share of its overall water-storage system. On the Tuolumne itself, the City presently has storage rights in Cherry and Eleanor Reservoirs and most significantly in New Don Pedro Reservoir, which holds six times more water than Hetch Hetchy. While O'Shaughnessy Dam was an engineering marvel of its time and Hetch Hetchy remains an integral part of San Francisco's water-storage and -delivery system, Don Pedro has become the Tuolumne River watershed's workhorse.

Don Pedro was built as a cooperative venture by TID and MID, with considerable funding provided by San Francisco. But, as discussed in greater detail in Appendix C, its authorization and construction followed lengthy and combative negotiations between San Francisco and the Districts. Eventually, four separate agreements were required before the parties could reach the accommodation that led to New Don Pedro's construction.

In consideration of San Francisco's sharing of its construction costs, the City effectively secured a right to store water in Don Pedro. This is an unusual storage right, however, as San Francisco presently has no physical means for diverting water from Don Pedro to the San Joaquin Valley pipelines that it uses to convey Hetch Hetchy water to the Bay Area. In essence, San Francisco maintains a storage "bank account" in Don Pedro, which allows it to divert and use Tuolumne River water that is within TID's and MID's senior appropriative-water-right supply upstream of Don Pedro, and to credit TID and MID with equivalent amounts of San Francisco's water stored in Don Pedro downstream.

Finally, San Francisco owns, holds rights to store water in, and operates several major dams and reservoirs in the Bay Area. Among them is the Calaveras facility (in the Alameda Creek watershed), acquired in 1930 when the City took over the Spring Valley Water Company. San Francisco is presently investigating possibilities for increasing the size of Calaveras Dam and Reservoir—in some scenarios by as much as, or even more than, the storage capacity of O'Shaughnessy Dam and Reservoir.

SAN FRANCISCO'S RIGHTS TO GENERATE POWER ON THE TUOLUMNE RIVER

As has been described in greater detail in prior chapters, San Francisco's priority in operating its Tuolumne River system is to assure water deliveries to itself and its water customers. Nevertheless, the generation of hydroelectric power at the City's three Tuolumne River powerhouses is a valuable source of low-cost electricity for satisfying its own and the Districts' municipal power needs. This generation also has been a source of revenue for San Francisco.

Unlike most other hydroelectric plants in the United States, San Francisco's Tuolumne River facilities are not subject to the regulatory oversight of the Federal Energy Regulatory Commission. Instead, by the terms of the Raker Act, they are overseen principally by the Secretary of the Interior, although the Secretary of Agriculture has jurisdiction over aspects of their operations that affect Stanislaus National Forest and the State of California has nascent jurisdiction to set prices for the power they generate.

In 1913, when the Raker Act was passed, and for many years thereafter, the struggles between public and private power were among the most contentious public-policy battles in the nation. Accordingly, it is not that remarkable that the Raker Act gave the Secretary of the Interior discretion to require San Francisco to develop additional hydroelectric power facilities beyond what San Francisco might have wanted to develop and, absent San Francisco's willingness to pursue that development, to develop the additional facilities on his or her own.

In addition, the Raker Act prohibited the sale of power by San Francisco "to private persons or corporations," while it required that any electricity in "excess" of San Francisco's "actual municipal public purposes" be sold to TID, MID, and municipalities within those districts. But the definition of excess depends on whether electricity required for municipal purposes includes what is used by San Francisco's wholesale water-supply customers. Having recently reorganized themselves under the auspices of a new agency—the Bay Area Water Supply and Conservation Agency (BAWSCA)—the customers could not only have a vital stake in San Francisco's water system but, if they assert a priority and prevail in pursuing that line of argument, in its hydroelectric system as well.

Legal and institutional aspects of restoration

CHANGES IN POINTS OF DIVERSION, WATER QUANTITIES AND STORAGE LOCATIONS

In examining the different scenarios by which Hetch Hetchy Valley might be restored to its natural splendor, this report has considered alternatives regarding points of diversion of water, levels of diversion from those points, and storage locations. None of these alternatives is free of legal and institutional constraints. Like all other major California waterways, the Tuolumne River has had a long history of legal wrangling and negotiation. Any potential change in its management or exploitation will be carefully scrutinized by a wide range of stakeholders.

The analysis in Appendix C examines in considerable detail the concerns that are likely to be raised should San Francisco propose either to increase its diversions from the river or even just to enhance its physical capability to do so. While San Francisco presently takes considerably less water from the Tuolumne than the amount to which it lays claim, others whose interests lie downstream of the City's current points of diversion may well raise substantial objections to any action—such as a fourth pipeline across the San Joaquin Valley—that San Francisco may soon formally propose as part of its Capital Improvement Program.

Less clear, however, is how downstream interests will react if it is formally proposed that San Francisco reduce its ability to divert water upstream, in the context of a Hetch Hetchy restoration program. The most challenging, but also potentially the most fruitful, proposal would involve modifications in San Francisco's storage and diversion capabilities with respect to Don Pedro Reservoir. As senior water-rights holders on the Tuolumne River and as the principal operators of Don Pedro, TID and MID can fairly be expected to examine with great diligence any proposed significant changes in Don Pedro's configuration and use. While they might view a reduction in San Francisco's capability to divert water upstream of Don Pedro with some favor, they could also be expected to worry about an increased role in Don Pedro operations that San Francisco might seek as part of any Hetch Hetchy Valley restoration scenario. And perhaps of even greater concern would be a proposal to have San Francisco divert significant quantities of water from or near Don Pedro itself. Building, operating and using such a connection, however, could obviously be one of San Francisco's most promising water-supply options in lieu of Hetch Hetchy.

A Don Pedro physical-access and operations negotiation involving San Francisco, the Districts and, at least on some aspects of these matters, downstream interests, will be an exceedingly intricate enterprise. While perhaps not quite at the scale or with as many stakeholders as some other recent water-related negotiations in the region—such as those that led to the 1994 Bay Delta Accord, the 2000 CALFED Record of Decision, and the 2003 Quantification Settlement Agreement among California's Colorado River interests—a new Don Pedro agreement would certainly rival them both for its importance and in its likely complexity. Each involved party would seek assurances that its interests will be protected and that the protections are memorialized in the final agreements reached. To achieve these ends, not only would the immediately involved parties be called upon to exercise real statesmanship but so would others. The state and federal governments, for example, would surely need to make important contributions, in their regulatory capacities and otherwise.

Not quite comparable, but also complex and difficult, will be the negotiations involved in any plan to increase the storage capacity of Calaveras Dam and Reservoir in the East Bay hills. The seismic issues involved (with a significant urban population downstream of the dam) as well as environmental issues (in which Calaveras is already embroiled and that any proposal to modify the dam could be expected to complicate), will provide all of the affected interests with great challenges.

Although in recent years both the Contra Costa Water District and the Metropolitan Water District of Southern California have successfully built new off-stream storage dams to serve their customers, many other California agencies have found it difficult to build additional storage facilities for financial reasons and in some cases also because of environmental concerns. While Calaveras would serve San Francisco for the most part as an off-stream storage site, it would also affect on-stream fishery and flow interests in a much more substantial way than projects like the recently constructed Los Vaqueros and Diamond Valley Reservoirs have done. Accordingly, if San Francisco is to upgrade Calaveras, it will need to design and operate an enlarged facility to fulfill the requirements of the National Environmental Policy Act, the California Environmental Quality Act, and federal and state endangered-species laws. That is, Calaveras must function in a manner that not only maintains existing values downstream of the dam-and addresses the impacts of flooding more habitat, but that actually enhances downstream values and more than mitigates for the habitat loss.

LINKING SAN FRANCISCO'S SYSTEM TO THE DELTA

For the century and a half during which it has been a major metropolis, San Francisco has run its water-supply system with little connection to the much larger system in the Sacramento-San Joaquin Delta. By contrast, almost all of urban southern California and much of the South, North, and East Bay Areas, as well as huge swaths of San Joaquin Valley agriculture, regularly obtain much if not all of their water from the Delta. Moreover, many others divert water upstream of the Delta pursuant to contracts with the federal government's Central Valley Project. But as an upstream diverter with relatively old water rights, and in possession of water-storage and delivery systems built without significant federal and state involvement, San Francisco's system has operated mostly independently of Delta-related considerations.

This circumstance is likely not to continue over the next few decades, whatever the future of Hetch Hetchy Valley. In the CALFED Record of Decision formally adopted by the Secretaries of Interior (U.S.) and Resources (California) in September 2000, considerable emphasis was placed on greater regional coordination both of water-supply planning and of current and future water-supply infrastructure. Prompted partly by this state-federal initiative and in part on their own initiative, San Francisco and other Bay Area water-supply-delivery agencies have increasingly been exploring regional interconnections in recent years. Such networking would serve both as a hedge against emergency interruptions in their service areas' water supplies and as a possible way to address future water shortages in a cooperative and cost-effective manner.

For San Francisco to strengthen its linkages with regional neighbors, it would surely be advisable for the City to expand its ability to acquire and deliver water from the Delta, even if only in drought periods. The legal complexities that will attend this potential diversification of San Francisco's water supply are many, and only a sketch of what may be involved is warranted here. For at least four decades, all water users in the entire Central Valley watershed have at least nominally been participants in a series of regulatory proceedings before the State Water Resources Control Board. Two major issues have been at play in those proceedings: the priorities of various water-rights holders in the watershed, and these holders' obligations to ensure that various indices of water quality and fisheries protection in the Sacramento-San Joaquin Delta estuary are met.

In the best case, as described more fully in Appendix C, San Francisco should be able to successfully assert that the seniority of its water rights in the Tuolumne River are sufficient to allow diversion of amounts equivalent to those rights downstream in the Delta. Certainly such a position would have the precedents in its favor that applaud the multiple use of water and that recognize the value of the increased in-stream flows in the Tuolumne that would accompany a regime in which San Francisco is diverting more water downstream.

When San Francisco proposes to use a Delta water source that is not based on its Tuolumne water rights, however, its prospects are likely to be less favorable. Although, as noted above, municipal and domestic uses of water are entitled to some preference in California water law, the extent of this preference is unclear; users who divert for agricultural purposes and who have senior water rights can be expected to contest any assertion of a municipal or domestic preference. However, San Francisco, like other urban agencies in recent years that have purchased or leased agricultural water rights in the Sacramento-San Joaquin watershed, should be able to successfully consummate those acquisitions. They would be subject, however, to outflow requirements or other restrictions that the State Water Resources Control Board or others—such as the Bureau of Reclamation (when federal water is involved) or the California Department of Water Resources (should its aqueducts be used for conveying any of the water)—may place on the acquisitions.

California water law is still evolving, especially where the Sacramento-San Joaquin Delta estuary is concerned, and the demands on the Delta system have been growing in all sectors. Thus the regulatory, legal, and political responses to these demands cannot yet be said to have produced a situation wherein any potential diverter from the Delta can be wholly comfortable that its water supplies will be available under all circumstances. That said, as the CALFED Record of Decision noted, it is in the state's interest that San Francisco be better interconnected to its neighbors and that over time more of San Francisco's supplies be diverted downstream. To make progress on these objectives in a manner that also meets the City's interests in securing a reliable high-quality water supply, San Francisco must receive assurances commensurate with those relied on by other major Delta-water diverters.

GROUNDWATER STORAGE AND CONJUNCTIVE USE

California water users have been using groundwater and surface water conjunctively for many years. Indeed, some of the state's most renowned water projects, including the Central Valley Project, the State Water Project, and even several elements of Southern California's Colorado River delivery system, were designed to deliver surface water when it is relatively plentiful and to rely on groundwater storage when there is insufficient surface supply. As the number of new surface-water-supply projects has dwindled in recent decades, California water agencies have increasingly turned to new conjunctive approaches in which they've contractually agreed to store some of their surface water in groundwater basins over which others have effective control. As noted in Chapter 3, several Bay Area water agencies already have groundwater banking and exchange programs in place in the San Joaquin Valley.

The San Francisco Public Utilities Commission (SFPUC) is not among those agencies, however. While the groundwater basins in the vicinity of the Tuolumne River currently have very significant amounts of water in storage, it is also the case that the districts overlying those basins have thus far shown little inclination to negotiate groundwater banking and exchange agreements with San Francisco. The obstacles to successful negotiation that would allow San Francisco to avail itself of this storage capacity are not so formidable, however, that the City should consider ending its pursuit of this option. Although it took over 30 years to conclude the surface-water-sharing agreement between San Francisco, TID, and MID that led to the construction of New Don Pedro, an agreement for sharing underground storage capacity should not take this long. Ultimately, what is crucial is that those communities overlying the basins—and that are directly affected by any conjunctive-use scheme—be assured that they will receive benefits commensurate with the value of the assets they have agreed to share.

TRANSFERS

Just as groundwater-storage and conjunctive-use agreements have become increasingly common in recent years, so have voluntary transfers of water. For over two decades, the California legislature has encouraged transfers, principally by assuring that water-right priority is not forfeited when an entitled user chooses to conserve water and then sell or lease it to some other user. In most cases, these transfers have been short-term, usually for one year, one growing season, or even several years in a row. But in some cases—especially where an urban user, or an agricultural user with a significant investment in permanent plantings, is involved as a prospective buyer—the buyer seeks assurances in advance that a supplemental water supply will be available in those future circumstances when it is short of its base supplies. In these cases, effectively option arrangements, the prospective seller retains the water purchased in years when the buyer does not call its option. This allows the seller to make a premium price by selling its water in dry periods, but also to continue to use its water during wetter periods in more conventional ways.

For communities concerned about the reduced economic activity that may occur as agencies sell water outside their localities, it should be noted that these occasional sales could provide an overall benefit. Sellers may use the supplemental income they derive from sales in dry years to upgrade the efficiency of their water-delivery systems or otherwise improve their farming operations. Although the legislature is still grappling with issues dealing with the community impacts of transfers and issues surrounding access to common-carrier aqueducts and environmental-impact review also remain contentious, few would contend that transfers are not here to stay as a major source of supplemental water supplies for entities looking to assure additional deliveries during future drought periods.

POWER

Chapter 9 of this report analyzes the probable changes in hydroelectric generation associated with different scenarios for restoring Hetch Hetchy Valley. Because all scenarios would involve at least some reduction in the capacity of the Kirkwood and Moccasin powerhouses, all would reduce the electricity available to these sources' present and future beneficiaries. As such, it is at least arguable that restoration proposals would run afoul of the Raker Act's emphasis on maximizing the production of public power from the Tuolumne River's water supply. Although this federal law is now over 90 years old, it is not inconsistent with more recent expressions of Congressional intent that have encouraged the development and use of hydroelectric power to serve the public's electrical-energy needs.

On the other hand, in 1921, less than a decade after it passed the Raker Act, Congress passed another law prohibiting the issuance of licenses for hydroelectric projects in national parks. In recent years Congress and the Federal Energy Regulatory Commission have authorized and funded the decommissioning of dams in various locations when they have perceived the environmental and social benefits of decommissioning to be greater than the continued utility of operating the dams as hydroelectric facilities.

In any case, a proposed change as significant as returning Hetch Hetchy Valley to Yosemite National Park will require explicit Congressional action for reasons beyond its hydroelectric-power implications. It will also require, at the regional level, significant negotiations between San Francisco, the Districts, and potentially San Francisco's customers in BAWSCA.

REGULATORY CONSIDERATIONS

San Francisco's potential plans to add new storage, conveyance capacity, and treatment capability to its water-delivery system will certainly attract the attention of a wide range of regulatory agencies responsible for protection of the nation's and state's environment and natural resources. But only one of them will have overall authority in this case. In 2003 Congress passed legislation, principally promoted by San Francisco and sponsored by Representative Nancy Pelosi, consolidating environmental review of San Francisco's Capital Improvement Program (CIP) in one location: the San Francisco District Office of the U.S. Army Corps of Engineers. Thus it will be in proceedings launched by the Corps where the merits of Calaveras Dam enlargement, construction of a fourth pipeline across the San Joaquin Valley, and expansion of the Sunol Water Treatment Plant will be most intensively studied. How this review will take place, whether it be project by project, or whether a comprehensive Environmental Impact Statement is required, is not yet known.

A comprehensive analysis of the proposed restoration of Hetch Hetchy Valley could well be an optimal course for the Corps, and not only because such a plan would involve several components of San Francisco's own plans for the future. A comprehensive Corps process would also provide a rare opportunity for interested federal and state agencies to work together for a common purpose.

Participation in the process by the U.S. Bureau of Reclamation and National Park Service would be especially valuable in providing expertise and on-the-ground knowledge and commitment. Indeed, the SFPUC's general manager wrote to Rep. Pelosi in 2003 that "these agencies play prominent roles with regards to the Hetch Hetchy system and in the greater California water community." Both agencies, moreover, report to the Secretary of the Interior, the principal official designated by Congress to administer the Raker Act. Similar expertise resides at the state level in the Department of Water Resources, the Department of Parks and Recreation, and the Department of Fish and Game, all of which are housed within the State Resources Agency.

None of these entities—nor others involved in the CIP review, such as the U.S. Fish and Wildlife Service (where responsibility resides to protect endangered species)—has the breadth of capability to conduct a comprehensive analysis of restoration alternatives on its own. Working together, especially in cooperation with San Francisco and with such other vitally interested parties as TID, MID, and BAWSCA, a comprehensive analysis could well be accomplished within the context of the Corps' process.

The Corps is not the only regulatory agency with an interest in San Francisco's system. The State Water Resources Control Board (SWRCB) is the regulatory entity principally responsible, along with the state courts, for assuring that the City is taking water in compliance with its state-granted water rights and that the public trust is being met with respect to its use of the Tuolumne River. The SWRCB is also responsible, again in parallel with the state courts, for assuring that San Francisco does not unreasonably use or divert water. Moreover, the SWRCB must assure that water-quality standards for the entire Sacramento-San Joaquin Delta watershed are adopted, implemented and enforced, and it will likely be called upon as well to review San Francisco's plans for the Alameda Creek watershed.

Meanwhile, the U.S. Environmental Protection Agency (EPA) and the California Department of Health Services (DHS) will no doubt continue to be critically involved in reviews not only of the drinking-water-quality aspects of San Francisco's system but also, more indirectly, of its general impacts on water quality and the environment. Ultimately, the EPA and DHS will have much to say about whether San Francisco can continue to avoid filtering the bulk of the water it supplies to its customers. In the last several decades the EPA has also taken considerable interest in assuring that the SWRCB does not renege on its duty to update and implement water-quality standards for the Bay Delta estuary, generally considered the most important on the Pacific Coast of the Americas.

Finally, although it does not have jurisdiction over San Francisco's Hetch Hetchy power generation, the Federal Energy Regulatory Commission—working with agencies such as the California Public Utilities Commission, the California Energy Commission, and the Independent System Operator—has overall responsibility for ensuring a reliable electricity supply in California. The state agencies in particular could be valuable in giving San Francisco and others assurance of replacement power supplies for those supplies forgone should Hetch Hetchy Valley be restored.

Conclusion

This chapter began by noting that no legal or institutional obstacles seem so formidable as to block consideration of the water-supply, water-quality, and replacement-power options entailed in the restoration of Hetch Hetchy Valley. Indeed, disparate authorities, including the Raker Act itself, the public-trust doctrine, and the injunctions of the California Constitution's Article X, section 2 against the unreasonable use or diversion of water, seem to *require* an ongoing duty to consider alternatives that might lead to the valley's restoration. Fortified by the procedural and substantive requirements of the National Environmental Policy Act and the California Environmental Quality Act, the Corps of Engineers review of San Francisco's Capital Improvement Program provides a forum for considering such alternatives.

However, it is also the case, as described in greater detail both elsewhere in this chapter and in the legal memorandum incorporated as Appendix C, that substantial legal and institutional hurdles must be overcome in order for a restoration scenario to actually come to pass.

Most significantly, Congress must amend and modernize the Raker Act and authorize an altered set of purposes for use of national-park land.

The State of California, in furtherance of various of its regulatory and management roles, will also need to act so as to assure San Francisco's water-use, diversion, and storage rights in a new configuration. It must also assure the City, the Turlock and Modesto Irrigation Districts, BAWSCA, and others that it will legally require a fair resolution—prior to implementation of any restoration scenario—of the myriad issues raised by such major changes in San Francisco's water-delivery and power-generation system. Meanwhile, these directly interested parties will need to negotiate new arrangements amongst themselves that equitably reflect the legitimate demands they all place on the Tuolumne River's capacity to provide water and generate power.

All this, as described in some detail in Chapter 10, cannot happen without incurring significant costs. In bearing that expense, it is not reasonable to ask San Francisco, its customers, and the Districts to act alone, independent of the broader state and national publics that would benefit from a restored Hetch Hetchy Valley. Thus it is apparent that ultimately both the state legislature (and/or the state's voting public) and the Congress will need not only to provide the legal assurances that would be required for any restoration scenario to succeed, but also to share significantly in funding the arrangements that ensue.

CHAPTER 12

Conclusion and recommendations

The analysis presented in this report shows that replacing the water-supply and hydropower benefits currently provided by Hetch Hetchy Reservoir can be accomplished in technologically feasible, safe, dependable and affordable ways. These solutions should be vigorously pursued.

A plan to restore Hetch Hetchy Valley should complement the Capital Improvement Program (CIP) for repairing and enhancing the water and power system of the San Francisco Public Utilities Commission (SFPUC). But given the broad public benefits that a restored valley would provide, not just to San Francisco but to California and the nation, state and federal agencies alike should provide assistance in the development of this plan, particularly for securing the needed staff and expertise.

Below, we outline steps that the SFPUC and other stakeholders should take to enable restoration of Hetch Hetchy Valley and to ensure that the costs and benefits of this undertaking are equitably distributed. We conclude by sketching how a public process to develop a restoration plan, proceeding in parallel with the SFPUC's CIP, should involve all stakeholders and key public agencies.

Water-system improvements

The SFPUC should continue to divert much of its water supply, during periods when the river has sufficient flow, high in the Tuolumne River watershed, at Early Intake. Our analysis indicates that most of the river's supplies currently diverted at Early Intake would still be available *without* Hetch Hetchy Reservoir.

CONVEYANCE

The SFPUC should build an intertie between its aqueduct and a point on the Tuolumne River at or below Don Pedro Reservoir. This intertie would enable the SFPUC to divert water supplies that are currently held in storage in Cherry Lake and Lake Eleanor Reservoirs and in the SFPUC's water bank in Don Pedro Reservoir. This intertie should be developed in cooperation with the Turlock and Modesto Irrigation Districts and should fully respect their water rights. Our analysis suggests that the SFPUC might derive about one-third of its total supply from a downstream diversion point, that in combination with upstream run-of-river diversions and Bay Area supplies would fully meet customers' needs in four out of five years, on average.

The SFPUC should carefully evaluate the supply-reliability benefits that might be gained from construction of an intertie to the California Aqueduct or Delta-Mendota Canal. While Tuolumne supplies are less costly to treat, such an intertie would offer increased reliability in the event of a drought or system emergency—it would provide valuable insurance even if it were never used.

The SFPUC should repair the pipelines in the Bay Area that are identified in its Capital Improvement Program. The reliability of its local conveyance system is inadequate at present.

WATER SUPPLY

In most years, the SFPUC has sufficient supply even without Hetch Hetchy Reservoir. The incremental contribution of Hetch Hetchy Reservoir is small, but it has been important in droughts.

The SFPUC and its customers should, in accordance with the Raker Act, maximize water supplies in the Bay Area, including those made possible by increased conservation and recycling.

The SFPUC should investigate additional dry-year supply alternatives. It should strongly consider transfer and groundwater-exchange agreements similar to those that agencies throughout California have successfully established in recent years. The recent experience of other urban agencies in California has shown that negotiating such arrangements requires persistence and flexibility, but the results have often proved to be valuable investments.

The SFPUC should rebuild Calaveras Reservoir. The ultimate size and configuration of the enhanced facility should be a sensitive function of water-supply needs, costs, dam safety and environmental issues on Calaveras and Alameda Creeks.

FLOOD CONTROL

While Hetch Hetchy Reservoir provides no explicit flood-control space, practices for operating it may result in incidental flood-control protection. Additional analysis of overall flood control on the Tuolumne River, including both available reservoir space and river channel capacity, should be pursued.

TREATMENT

Additional water-treatment facilities should be in place and operational before Hetch Hetchy Valley is restored.

The potential for degraded water quality resulting from visitation to a restored Hetch Hetchy Valley should be addressed in the valley's management plan.

Further sampling of alternative water sources should be conducted for concentrations of the chemical pollutant MTBE. If it is found to be present in significant quantities, the effect of MTBE being phased out of gasoline production in California should be investigated.

Whether or not restoration occurs, the SFPUC should thoroughly explore the benefits of filtering all of its water supplies. Expansion of water-treatment facilities would allow the SFPUC to use a variety of alternative supplies in the event of a drought or system emergency.

Additional analysis should examine a range of public-health issues, including the threats of giardia and cryptosporidia in the current SFPUC system, and the extent to which conventional treatment,

TIM CONNOR

In most years, the SFPUC has sufficient supply even without Hetch Hetchy Reservoir. The incremental contribution of Hetch Hetchy Reservoir is small, but has been important in droughts.

including filtration, can effectively treat water for Bay Area customers.

Hydropower alternatives

The potential for modifying the Canyon Power Tunnel to allow continued use of Kirkwood powerhouse should be investigated. The study should also address the impacts on recreational and scenic values in Yosemite National Park of constructing a diversion dam in Hetch Hetchy Valley.

The potential should be examined for modifying the SFPUC's hydropower operations to increase production of valuable on-peak energy, but without impairing the reliability of water supplies. This analysis should also identify possible adverse environmental impacts resulting from any proposed changes.

Opportunities should be fully explored for obviating the need for energy from the SFPUC's hydroelectric facilities by investing in cost-effective energy-efficiency measures and expanding dynamic-pricing programs.

Opportunities should be pursued for purchasing renewable energy or developing renewable-energy facilities to replace a significant fraction of present capacity. The extent to which gas-fired energy will be needed to "firm up" such replacement supplies should also be investigated.

Approaches should be assessed for offsetting all emissions, including greenhouse gases, from any gas-fired generation used to replace Hetch Hetchy hydropower.

Seasonal and daily patterns of San Francisco's use of Hetch Hetchy hydropower should be analyzed in order to determine how the SFPUC's power-purchase needs and the availability of surplus energy to sell to the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) would change as a result of restoring the valley. This information could then be used to estimate the financial impacts on the SFPUC and the Districts, thereby providing the basis for any compensation for increased power-procurement costs.

Process to develop a restoration plan

The water and power alternatives identified in this report are intended to serve as a starting point for a broad public effort to develop a comprehensive restoration plan. As alternatives are further developed, so should plans proceed for restoration and subsequent management of Hetch Hetchy Valley as one of the crown jewels of America's National Park System. In any case, water and power alternatives must be in place before the valley's restoration can begin.

Any feasible alternative should:

- ensure a reliable supply of high-quality water to residents and businesses in the San Francisco Bay Area;
- include a plan to replace the hydropower that Hetch Hetchy Reservoir makes possible;
- ensure that the water and power benefits provided by the Tuolumne River to other communities, especially those served by the Turlock and Modesto Irrigation Districts, do not diminish.

A public process to develop a Hetch Hetchy Valley restoration plan should be initiated. This process should be closely linked to the San Francisco Public Utilities Commission's effort to implement its Capital Improvement Program. The restoration plan should be distinct from the CIP, however, in order that it not delay the important critical repairs that the SFPUC must immediately make on some parts of its system. Further, the public process should include leadership by the state and

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The Tuolumne River once meandered through wildflower-dotted meadows and groves of oaks, pines, and firs. A 1988 study by the National Park Service found that if the valley is drained Hetch Hetchy's plant and animal life would come back with some human assistance. This hand-tinted photograph suggests how a restored Hetch Hetchy Valley might appear.

federal governments to ensure that the interests and rights of affected communities and the broader public are reflected in the deliberations.

Replacing the water and power that the Hetch Hetchy Reservoir currently provides is the principal challenge to overcome if the valley is to be restored. The alternatives outlined in this report should be analyzed and refined not only by agencies that rely on the Tuolumne River, but also by the U.S. Bureau of Reclamation and the California Department of Water Resources, both of which have considerable expertise in these areas. The results should then be included in a public effort to develop and implement a restoration plan.

As the water and power elements of a restoration plan are developed, a simultaneous effort for restoring the valley floor and river channel should get under way. Similarly, plans for the management of a restored valley should be developed; we assume that the National Park Service, as the eventual steward of a restored Hetch Hetchy Valley, will take a leadership role.

A restoration plan will succeed most quickly and efficiently if it shows clear respect for the rights of those who depend on the Tuolumne River. These stakeholders include San Francisco, the SFPUC's customers in the Bay Area Water Supply and Conservation Agency, and in Groveland, TID, and MID.

The public process to develop a restoration plan would be best initiated in parallel to the SFPUC's CIP and should be conducted in full compliance with the National Environmental Policy Act and the California Environmental Quality Act, as well as other relevant laws.

As alternatives are refined, the public process should develop criteria—including, for example, assessment of the benefits that a restored valley would bring—to ensure that the costs and benefits of restoration are fairly distributed. Funding sources among government agencies at all levels—federal, state and local—should be explored. Public willingness to participate in funding restoration should also be pursued, as should private philanthropy.

The opportunity to restore Hetch Hetchy Valley is unique. The time to begin the process is now.

Glossary of technical terms

Water management terms

Acre-foot The volume of water, one foot deep, that would cover an acre. An acre-foot is enough water to supply two to three typical households for one year. *Related terms:* thousand acre-feet, million acre-feet.

CALSIM Computer planning model developed jointly by the California and United States governments to simulate operations of the State Water Project and Central Valley Project.

CALVIN Computer planning model developed the University of California, Davis, to investigate opportunities for economically efficient management of water in California.

Cubic feet per second A standard measurement of water flow. One cubic foot per second is approximately equal to two acre-feet per day or 724 acre-feet per year.

Groundwater exchange A trading system, normally between urban and agricultural agencies, that encourages efficient uses of groundwater-storage basins.

HHSM-LSM Computer planning model developed by the San Francisco Public Utilities Commission to simulate operations of its water-supply system.

Intertie A pipeline that connects a water-storage system to a water-supply system.

Millions of gallons per day A standard measure of an urban agency's average water use. One million gallons per day is about one and a half cubic feet per second.

Run-of-river diversion A diversion of water from a stream made possible by the natural flow of the river (i.e., without any release of water from a reservoir).

Transfer Water purchased through a market transaction.

TREWSSIM Computer planning model developed by Environmental Defense to investigate alternatives to Hetch Hetchy Reservoir.

Electric power terms

Capacity factor The ratio of actual electrical energy produced over a given period of time to the amount of energy that could theoretically be produced at full operational power over the same period. A power plant that runs constantly would have a capacity factor of 100 percent.

Cogen Short for cogeneration, a process in which excess heat from an industrial process is used to produce electricity.

MMBtu Millions of British thermal units. One Btu is the amount of heat required to raise the temperature of 1 lb of water 1 degree F. (MM = thousand thousands, or millions).

Peak demand The maximum power usage occurring in a given period of time. Typically, in California, the annual peak demand occurs during hot summer-weekday afternoons.

Peaking capability The ability of a powerplant to increase or decrease its output rapidly in response to short-term changes in electricity demand.

Spinning reserve A powerplant that is not generating power but can rapidly be turned on if additional supplies are needed is on "spinning reserve."

Spot market A market in which electricity is bought or sold for immediate or very-near-term delivery, usually for a period of 30 days or less. There is no long-term contract between the buyer and the seller.

Transmission capacity The maximum amount of electricity that can be transmitted through a particular set of power lines.

Watt Basic unit of electric power, describing the rate at which energy is being produced or used. Powerplant capacities are normally measured in megawatts (MW). *Related terms:* kilowatt (1000 watts), megawatts (1,000,000 watts).

Watt-hour Basic unit of electric energy, describing the amount of energy running through an electrical circuit for one hour with 1 watt of power being supplied. *Related terms:* kilowatt-hour (1000 watt-hours), megawatt-hour (1,000,000 watt-hours), gigawatt-hour (1,000,000,000 watt-hours). Residential electric bills are normally measured in kilowatt-hours. Powerplant generation is normally measured in gigawatt-hours.

Water quality terms

Bacteria A potentially pathogenic single-celled organism with no nucleus.

Cyst A capsule or protective coating with which many protozoans and some bacteria surround themselves to resist destruction from disinfection.

Filtration The physical (not chemical) process of removing solid particles from water.

Oocyst Fertilized-egg form of protozoa, encapsulated in a tough cyst-like shell.

Pathogen An agent that causes disease.

Potable water Water that is safe to drink.

Protozoa A potentially pathogenic single-celled organism with a nucleus.

Turbidity The cloudiness, or opaqueness, of water caused by the presence of small suspended particles.

Virus A potentially pathogenic parasite that is unable to replicate without a host cell.

Acronyms

BACT Best Available Control Technology

BARWRP Bay Area Regional Water Recycling Program

BAWSCA Bay Area Water Supply and Conservation Agency

CAISO California Independent Systems Operator

CALFED California and federal Bay-Delta program

CALSIM California Water Resources Simulation

CALVIN California Value Integrated Network

CEC California Energy Commission

cfs cubic feet per second

CIP Capitol Improvement Program

CO_2 carbon dioxide

CPUC California Public Utilities Commission

CUWCC California Urban Water Conservation Council

DWR Department of Water Resources

EIR Environmental Impact Report

EIS Environmental Impact Statement

EOA Eisenberg, Olivieri and Associates

EWA Environmental Water Account

FERC Federal Energy Regulatory Commission

GPS Global Positioning System

GWh gigawatt-hour

IID Imperial Irrigation District

KWH kilowatt-hour

LADWP Los Angeles Department of Water and Power

MAF million acre-feet

mcg/L micrograms/liter

MGD million gallons per day

MID Modesto Irrigation District

MRP market reference price

M-S-R Modesto Irrigation District, Santa Clara, and Redding Public Power Agency

MTBE Methyl tertiary-butyl Ether

MW megawatt

MWD Metropolitan Water District

MWh megawatt-hour

NO_x nitrogen oxides

NPDWR National Primary Drinking Water Regulations

NPS National Park Service

O&M Operations and Maintenance

PG&E Pacific Gas and Electric Co.

PVID Palo Verde Irrigation District

ROR run-of-river

RPS Renewable Portfolio Standard

SDCWA San Diego County Water Authority

SEIR Supplemental Environmental Impact Report

SEIS Supplemental Environmental Impact Statement

SFPUC San Francisco Public Utilites Commission

SO_x sulfur oxides

SWP State Water Project

TAF Thousands of Acre-Feet

TID Turlock Irrigation District

TREWSSIM Tuolumne River Equivalent Water Supply Simulation

WAPA Western Area Power Administration

WSMP Water Supply Master Plan

Notes

Chapter 2

[1] http://www.nps.gov/yose/nature/history.htm.
[2] *National Parks: The American Experience,* Alfred Runte, 1987.
[3] *Wilderness and the American Mind,* Roderick Nash, 1982.
[4] "The Annual Report of the President" of the Spring Valley Water Company, presented to the stockholders, 1907.
[5] *Sacramento Bee,* April 21, 2002.
[6] *New York Times,* October 12, 1913.
[7] *Sacramento Bee,* April 21, 2002.
[8] Nash, op. cit.
[9] The Institution of Engineers of Ireland, http://www.realizedvision.com/mos.htm.
[10] Cerny, Susan. April 26, 2004. Hetch Hetchy and Michael O'Shaughnessy. *San Francisco Chronicle.*
[11] Courtesy of the Bancroft Library.
[12] San Francisco Public Utilities Commission, http://sfwater.org/detail.cfm/MSC_ID/37/MTO_ID/NULL/MC_ID/5/C_ID/1184/holdSession/1.

Chapter 3

[1] B160-98, The California State Water Plan, California Department of Water Resources (DWR), November 1998.
[2] University of California Cooperative Extension, Sample Costs to Produce Alfalfa Hay, 2003; Sample Costs to Produce Tomatoes, 2002; and Sample Costs to Produce Mixed Melons, 2003.
[3] B160-03, Volume 2 (Administrative Draft), Resource Management Strategies, DWR, 2004.
[4] Personal communication with Michael Carlin, Planning Director for the SFPUC.
[5] "Translating Concept into Reality," DWR, State Water Project Analysis, 1993.
[6] B160-03, Volume 2 (Administrative Draft), Resource Management Strategies, DWR, 2004.
[7] Most of these supplies were purchased for the Environmental Water Account (EWA) of the CALFED Bay-Delta program, a collaboration of state and federal agencies.
[8] Email from Dirk Reed of MWD (April 30, 2004).
[9] City and County of San Francisco Hetch Hetchy Water and Power, Reconnaissance Evaluation of Alternative Sites for Groundwater Banking, Bookman-Edmonston Engineering Inc, and Luhdorff and Scalmanini Consulting Engineers, unpublished work July 1993.
[10] Water Recycling 2030, California Recycled Water Task Force Report, 2003.
[11] Southern California Comprehensive Water Reclamation and Reuse Study, Phase II, Final Report (Draft), 2000.
[12] Personal communication with Carol Munoz, SFPUC, June 1, 2004.
[13] B160-03, Volume 2, Resource Management Strategies.

Chapter 4

[1] California Energy Commission (CEC), 2003 Integrated Energy Policy Report, Pub. No. 100-03-019, December 2003, p. 10.
[2] CEC, op. cit., p. 10.
[3] CEC, op. cit., p. 12.
[4] Jeffrey F. Mount, *California's River and Streams,* 1995.
[5] University of California, Davis (Centers for Water and Wildland Resources), Status of the Sierra Nevada, June 1996.
[6] Based upon data reported to the California Energy Commission by PG&E, SFPUC and the Central Valley Project. The compound growth rate in energy use has been 0.7 percent/year since 1990.
[7] Based upon San Francisco's reported sales to ultimate customers in San Francisco and San Mateo Counties (CEC filing). These figures include reported energy use on form EIA-861 and sales to the airport (located in San Mateo County) on EIA-412.
[8] Turlock Irrigation District Annual Report, 2003.
[9] Modesto Irrigation District Annual Report, 2002.
[10] California Urban Water Conservation Council (CUWCC), "Projected Water Demand Reductions Derived from CEC Proposed Water Factor Standards," January 2004.
[11] http://www.sbvmwd.com/About%20Pages/aboutthe.htm.

Chapter 5

[1] SFPUC Water Supply Master Plan, April 2000.

[2] Due to flood control requirements, the maximum allowable storage capacity of Don Pedro varies throughout the year. The figures provided are the average storage values at the end of June, when the danger of flooding from rainfall or snowmelt has subsided.
[3] SF Electricity Resource Plan, p. 21
[4] Ibid, p. 22
[5] Source: KPMG Inc., Independent Auditor's Report for Hetch Hetchy Water and Power, Nov. 25, 2003, p. 2.
[6] Plan, p. 22.

Chapter 6

[1] Updated information about the Capital Improvement Program is available at the SFPUC website: http://sfwater.org/home.cfm. Also contact the SFPUC for a copy of its Water Supply Master Plan (April 2000) and the Water Supply Master Plan Technical Memoranda (1998).
[2] This report assumes no change in the currently permitted Delta export capacities or in related protective criteria.

Chapter 7

[1] See http://modeling.water.ca.gov/hydro/model/index.html for a description of CALSIM.
[2] For additional information on TREWSSIM, contact Environmental Defense.
[3] The SFPUC identifies demand in terms of millions of gallons per day (MGD), averaged over a year, rather than thousands of acre-feet (TAF). The following equivalences apply: 290 TAF/year = 260 MGD; 339 TAF/year = 303 MGD.
[4] This report uses the California Department of Water Resources' San Joaquin Basin 60-20-20 index to define which years are "critically dry." (Between 1922 and 1994, 16 years were so classified.) See http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.
[5] There is no specified flood-control space provided at Hetch Hetchy Reservoir, as the requirement was moved downstream to Don Pedro Reservoir when it was completed in 1970. The SFPUC has indicated, however, that it allows a maximum level of storage at Hetch Hetchy Reservoir of 330 TAF from October through March.
[6] The SFPUC has an agreement for sharing supply shortages with its municipal customers. Each retail agency normally develops its own plan for managing its limited supplies in dry years.
[7] The capacity of the four pipelines would be larger than 542 cubic feet per second but total conveyance would be constrained by the Coast Range Tunnel. This estimate may be conservative (see Appendix A).
[8] Modeling of releases from Cherry and Eleanor Reservoirs includes very few changes across the alternatives. Under a restoration scenario, minor changes in operating policy at these reservoirs may be appropriate to accommodate: (1) summer and fall flows at the Moccasin Creek fish hatchery; (2) summer and fall deliveries to the Groveland Community Services Districts; and (3) suitable summer whitewater-recreation flows for the Tuolumne River above Don Pedro reservoir.
[9] In order to maintain the carryover-storage objective without additional supplies under the current level of demand, deliveries in critically dry years were initially limited to 250 TAF. In critical years that followed other critical years, deliveries were further limited to 200 TAF.
[10] In order to maintain the carryover-storage objective without additional supplies under the projected increase in demand, deliveries in critically dry years were initially limited to 300 TAF. In critical years that followed other critical years, deliveries were further limited to 285 TAF.

Chapter 8

[1] SFPUC Website: http://sfwater.org/detail.cfm/MSC_ID/51/MTO_ID/63/MC_ID/10/C_ID/1456/#how.
[2] Balbus JM, Lang ME. 2001. Is the water safe for my baby? *Pediatr Clin North Am* 48(5):1129–1152.
[3] USEPA. March 2, 2001. Current Drinking Water Standards. http://www.epa.gov/safewater/mcl.html.
[4] http://www.dhs.ca.gov/ps/ddwem/chemicals/chemindex.htm.
[5] See Appendix B, Tables 2.3-2.6.
[6] Arsenic that occurs in well water, by contrast, is often present in a dissolved form, more difficult to filter, and a greater threat to human health.
[7] EOA's analysis is based on maximum projected values for volumes diverted from Don Pedro, the Delta and Bay Area Reservoirs.

The water quality of the alternatives described in Chapters 7 and 10 and in Appendix A falls within the range evaluated by EOA.

8 See http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/ for documentation of the CALVIN Model.

9 Personal communication with Richard Sykes, EBMUD. Data from the SFPUC was not available. The unit cost of treating supplies stored in Bay Area reservoirs varies widely.

Chapter 9

1 Preliminary analyses indicate that the gradent of the Canyon Tunnel is insufficient for capturing significant flows from a diversion dam. The pressure of water impounded behind O'Shaughnessy is needed to "push" water into the gently sloping tunnel. To capture adequate run-of-river flows so that Kirkwood powerhouse could continue generating, a steeper tunnel with a lower intake would need to be constructed. This costly undertaking could potentially be justified by hydropower revenues from continued operation of Kirkwood powerhouse.

2 San Francisco Chronicle. Jan. 10, 2001. "High cost of power hits S.F. budget, PUC to get little from Hetch Hetchy pact." p. A-13.

3 Personal communication with Michael Carlin, February 7, 2004.

4 If Kirkwood could not be modified to operate as a run-of-river facility, its entire base-case output would be unavailable in each month.

5 For the purposes of this analysis the peak period is assumed to be 12:00–6:00 PM on weekdays, as specified in Pacific Gas and Electric's time or use rates for commercial and industrial customers.

6 Western Electricity Coordinating Council. December 2003. *10 Year Coordinated Plan Summary*. p. 12.

7 California Energy Commission (CEC). December 2003. *2003 Integrated Energy Policy Report*. Pub. No. 100-03-019. p. 8.

8 Sources: CEC. Dec. 2003. *Public Interest Energy Strategies Report* (Integrated Energy Policy Report subsidiary volume). Report no. 100-03-012F, pp. 45–46; and Xenergy Inc. September 23, 2002. *California's Secret Energy Surplus: The Potential for Energy Efficiency*. Report prepared for the Hewlett Foundation and the Energy Foundation as part of the Hewlett Foundation Energy Series.

9 Discounted over 20 years at an eight-percent nominal rate and three-percent inflation rate. Note: the CEC report incorrectly states the discount rate as three-percent nominal.

10 CEC. Dec. 2003. *2003 Integrated Energy Policy Report*. Pub. No. 100-03-019.

11 Calculated using 2000 annual energy-use data for California and San Francisco County, as reported on the CEC's Website (http://www.energy.ca.gov/electricity/electricity_by_county_2000.html); and TID and MID's 2000 retail-sales data cited in the Districts' 2003 annual reports.

12 CEC. op. cit. p. 12.

13 Based on 2002 system peak demand for the County of San Francisco (900), TID (397) and MID (600). From San Francisco Energy Plan op. cit., and TID and MID 2002 Annual Reports.

14 As is the case with all generating technologies, some environmental impacts result from the manufacture of materials for renewable generating facilities as well as from the equipment used to build them.

15 CEC. December 2003. *Public Interest Strategies Report*. Pub. No. 100-03-012F. p. 94.

16 Offsets and "BACT" (Best Available Control Technology) are required in areas that are not in attainment of federal Clean Air Act air-quality standards. Most California counties are not in attainment.

17 Calculated using an emission factor of 420 tons/million KWh. Source: U.S. Environmental Protection Agency, *Compilation of Air Pollution Emissions Factors, AP-42,5th Edition, Stationary Point and Area Sources*, available online at http://www.epa.gov/ttn/chief/ap42/.

18 Statewide CO_2 emissions were 362.8 million tons in 1999, the last year for which data are publicly available. (CEC. November 2002. *Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999*. Pub. No. 600-02-001F. p. ES-6).

19 Personal communication with Sean Clark, Oregon Climate Trust, August 3, 2004.

20 Assumes 92 percent capacity factor for new combined-cycle gas-turbine baseload facilities.

21 California Energy Commission. June 2003. *Comparative Cost of California Central Station Generation Technologies*. Pub. No. 100-03-001F. p. 9.

22 Marcus, William. March 2003. *Clean and Affordable Power: How Los Angeles Can Reach*

20% Renewables without Raising Rates. Report prepared for Environment California Research and Policy Center and the Center for Energy Efficiency and Renewable Technologies. Available online at http://www.jbsenergy.com/Energy/Papers/|papers.htm

23 Pacific Gas and Electric Company. January 9, 2003. *Testimony Supporting PG&E's Application to Replace the Steam Generators in Units 1 and 2 of the Diablo Canyon Power Plant*, testimony submitted to the California Public Utilities Commission in A.04-01-009. pp. 6-8 to 6-10.

24 California Energy Commission. op. cit.

25 Marcus, p. 13.

26 CEC (2003). op. cit., p.3.

27 CEC. December 2003. *Public Interest Energy Strategies Report*. Pub. No. 100-03-012F. p.92.

Chapter 10

1 Boardman, A., D. Greenberg, A. Vining, and D. Weimer. 2001. *Cost-Benefit Analysis: Concepts and Practice.* 2nd Edition, Saddle River, NJ: Prentice Hall. pp. 249–250.

2 See op. cit., pp.236–249, for a survey of the literature on discount rates in cost-benefit analysis.

Chapter 11

1 Pub. L. No. 63-41 (Dec. 19, 1913), 38 Stats. 242.

2 *National Audubon Society v. Superior Court* (1983) 33 Cal. 3d 419.

3 *Environmental Defence Fund v. EBMUD,* (1980) 26 Cal. 3d 183.

APPENDIX A

Summary of technical analyses Hetch Hetchy Reservoir replacement alternatives

Prepared by Schlumberger Water Services for Environmental Defense

Summary of Technical Analyses
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services
June 10, 2004

Schlumberger Water Services (SWS) provided support on three key items for the Hetch Hetchy Replacement Alternatives:

- Conceptual level engineering and cost estimation for Calaveras Reservoir pumped storage, expansion of the Sunol Water Treatment Plant, groundwater storage in the eastern San Joaquin Valley, and an intertie to Don Pedro reservoir
- Hydraulic analysis of the Hetch Hetchy conveyance system
- Modeling of Delta diversion alternatives using CalSim II.

Calaveras Reservoir. The San Francisco Public Utilities Commission (SFPUC) Capital Improvement Program (CIP) assumed that the 97,000 acre-foot Calaveras Reservoir would be reconstructed to hold 670,000 acre-feet. However, since a reservoir of this size would require a saddle dam across the Calaveras Fault, the largest size under active consideration is 420,000 acre-feet where a saddle dam is not necessary. The CIP does not include Calaveras pumped storage facilities, but SFPUC staff has told Environmental Defense that it is likely to be added for an enlarged reservoir.

Replacement of Calaveras Reservoir is included as a high priority project in the SFPUC Capital Improvement Program. Improvements have a baseline cost of $150 million[1] for a 670,000 acre-foot reservoir. Detailed costs estimates for smaller reservoirs are not available. A simple analysis of reservoir volume suggests a 260,000 acre-foot reservoir would require a 315-foot-high dam. A 420,000 acre-foot reservoir would require an approximately 370-foot-high dam. Assuming the volume of embankment material for the dam is proportional to the cube of the height, and that construction cost is proportional to dam volume, capital cost for the 260,000 acre-foot reservoir would be about $60 million, and the 420,000 acre-foot reservoir would be about $90 million.

Sunol Water Treatment Plant. The SFPUC Capital Improvement Program includes an expansion of the Sunol Water Treatment Plant from the current 160 million gallons per day (mgd) to 240 mgd at a cost of $82 million. Each of the Hetch Hetchy replacement alternatives would further expand this facility to 400 mgd. A survey of recently designed or constructed treatment plants showed a fairly consistent unit cost of about one dollar per gallon per day of capacity. Cost for expansion to 400 mgd was estimated to cost $240 million (plus overhead and contingency as explained below).

Groundwater Storage. This analysis focuses on groundwater banking in the area downstream of Don Pedro Reservoir, principally in Modesto Irrigation District (MID), Turlock Irrigation District (TID), or the Eastside Water District (ESWD). In addition to

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[1] Presentation by Harlan L. Kelly, Jr., SFPUC Infrastructure AGM, December 1, 2003

taking its Tuolumne River water rights from Early Intake and from proposed facilities to divert from Don Pedro, SFPUC might supply MID and TID water needs from banked groundwater in exchange for MID or TID surface water supplies in dry years.

A number of potential sites for groundwater banking of SFPUC Tuolumne River water have been identified, including in the San Joaquin Valley, Sunol Valley, Westside Groundwater Basin on the Peninsula, and in Hetch Hetchy Valley. Hetch Hetchy Water and Power commissioned a 1993 study that examined more than 15 groundwater banking alternatives, plus a number of purchase and transfer opportunities[2]. Notably absent in the HHWP study is banking in the Modesto and Turlock Irrigation Districts, and in the Hetch Hetchy Valley. Banking in the Eastside Water District is summarized as "ideal for Hetch Hetchy" but is ranked as a "fair" opportunity because of institutional complexity.

The 1993 study reports that modeling efforts of the Eastside Water District area[3] show ESWD overdraft as about 50,000 acre-feet per year. Cumulative overdraft since 1970 is estimated as 1,000,000 acre-feet, of which one-quarter directly underlies ESWD.

Modesto Irrigation District is comprised of irrigated 64,000 acres within a 102,000 acre territory. Tuolumne River water is conveyed through 208 miles of canals and pipelines to 3,400 irrigation customers. Water is regulated by Don Pedro Reservoir and diverted to MID and TID at La Grange Dam. MID water is reregulated in the 28,000 acre-foot Modesto Reservoir. An average of about192,000 acre-feet per year is delivered at a current annual cost of $11.10 per acre.

Turlock Irrigation District imports approximately 435,000 acre-feet per year of surface water from Don Pedro Reservoir for agricultural irrigation after reregulation in Turlock Reservoir. TID also supplements its surface water supply with groundwater. The amount of groundwater pumped by TID varies from year to year depending on the availability of surface water and irrigation requirements. The average groundwater use for 1984-96 was 106,000 acre-feet per year[4]. TID pumps groundwater into a series of canals for distribution to users within its service district. Some individual growers within TID pump groundwater to augment their surface water allotment from TID while other growers rely exclusively on groundwater. Based on electrical power usage, groundwater extractions by individual growers in the TID service area are estimated to be approximately 123,000 acre-feet per year.

Eastside Water District currently uses groundwater as the source for the majority of its supply except for small amounts of surface water delivered by TID and MID during wet

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[2] City and County of San Francisco Hetch Hetchy Water and Power, Reconnaissance Evaluation of Alternative Sites for Groundwater Banking, Bookman-Edmonston Engineering Inc, and Luhdorff and Scalmanini Consulting Engineers, unpublished work July 1993
[3] The referenced modeling has not been found.
[4] A spreadsheet dated March 19, 2004 obtained from TID shows groundwater pumping from 1999 through 2003 ranged from 7281 to 42,207 acre-feet, and averaged 20,319 acre-feet per year

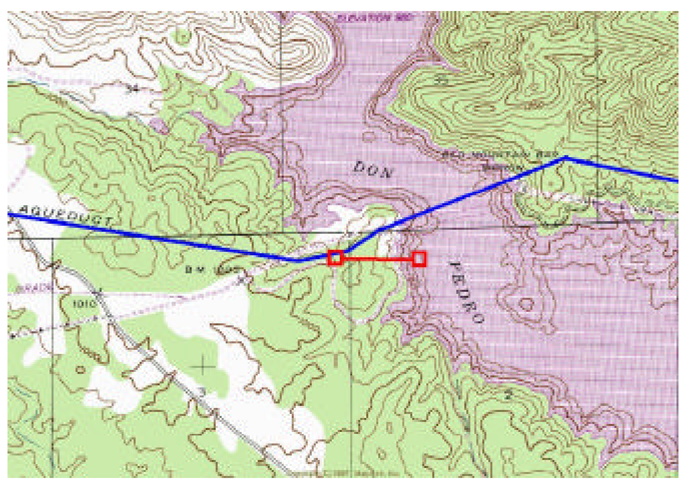
years. Irrigation water for agriculture is supplied by wells located throughout the ESWD. The average annual water requirement is approximately 155,000 acre-feet.

DWR Bulletin 118-2003 states that the well yields in the Modesto and Turlock groundwater average 1,000-2,000 gpm with some wells producing up to 4,500 gpm.

Groundwater could be recharged by both direct means (infiltration ponds or injection wells) or by indirect means (providing surface water to groundwater users in lieu of pumping). Recharge in this analysis is assumed to be a mix of pond and in-lieu recharge. A detailed layout of pond locations and in-lieu acres is beyond the scope of this study. Recharge ponds would need to be located east of the area underlain by the Corcoran clay, generally east of Highway 99. Areas with potential for in-lieu recharge (lands presently using groundwater) are scattered throughout MID and TID, and all of ESWD could be served in-lieu. For this analysis, it is assumed that areas within MID or TID could be served from existing surface water conveyances. Lands to the east might also be served from the districts' canal systems, but allowance has been made for pipeline trunk conveyances and pumping plants[5].

The modeled capacity of the groundwater recharge ponds is 200 cfs (145,000 acre-feet per year). The highest direct recharge modeled in any alternative averages 21,000 acre-feet per year (14 percent of capacity). This low utilization rate would allow adequate down time for pond maintenance. Consequently, no additional capacity has been assumed for peaking or maintenance.

The modeled capacity of in-lieu recharge is 386 cfs (23,300 acre-feet per month) for Alternatives B and C, and 283 cfs (17,100 acre-feet per month) for Alternatives D, E, and F. Using the 20 percent peak month for typical crop water needs of four acre-feet per acre, approximately 29,100 participating in-lieu acres would be required for Alternatives B and C. Approximately 21,400 participating in-lieu acres would be required for Alternatives D, E, and F



Don Pedro Intertie. The Hetch Hetchy Aqueduct crosses under Don Pedro Reservoir in the 2,500-foot-long Red Mountain Bar Siphon. For this analysis, a pumping plant at the west end of Red Mountain Bar Siphon would deliver Don Pedro Reservoir water to a regulating basin and vertical shaft connected to the Foothill Tunnel. The land rises rapidly on both sides of the Reservoir where a shaft could be located. A top elevation of about 900 feet would be compatible with the hydraulic gradeline of the tunnel.

[5] Assumes: Peak capacity piped conveyance to each section; Half of acres in served section take in-lieu water; Pump station with nominal 30' lift plus pipe friction losses.

Hydraulic Analysis. A simplified hydraulic analysis of the Hetch Hetchy conveyance system was performed for the portion from Moccasin to the Irvington Portal of the Coast Range Tunnel to provide an estimate of the system hydraulic grade line, flow capacity, and flow constraints. Using conservative assumptions, it is estimated that the overall flow through the existing system is limited to about 310 mgd. Adding a 78-inch diameter fourth barrel to the San Joaquin Pipelines would increase capacity to about 380 mgd, provided the overflow at the Tesla Portal could be extended 30 feet, and the existing facilities could be modified to withstand the additional 13 psi pressure. A similar analysis for a 90-inch fourth barrel suggests that 400 mgd could be conveyed through the system.

Conceptual-level Cost Estimates. Cost estimates were derived from the SFPUC Capital Improvement Plan and from unit cost factors. 20 percent has been added to all capital cost estimates as allowance for engineering, legal support, and administration (ELA). Cost estimates provided are conceptual level estimates which are expected to be between 70 and 150 percent of actual construction costs. A 25 percent contingency has been added to these estimates. With the contingency, the conceptual-level estimates are expected to be between 56 and 120 percent of actual construction costs. Financing costs of five percent were assumed. Energy costs of $0.055 were provided by Environmental Defense as representative of Hetch Hetchy's acquisition cost.

Six alternatives defined by Environmental Defense were analyzed using the TREWSSIM model and are summarized in the table below[6]. Each assumes that Hetch Hetchy Reservoir no longer exists. Three alternatives analyze the present 260 mgd demand level, and the other three assume a future demand of 303 mgd. Calaveras Reservoir is examined assuming it is rebuilt at the present 97,000 acre-foot size, as well as enlargement to 260,000 and 420,000 acre-feet. Pumped storage using an enlarged Calaveras Reservoir is assumed in four alternatives. The Sunol water treatment plant is assumed enlarged to 400 mgd for all alternatives. An interconnection from Don Pedro

	Alternative:	Base	CIP	A	B	C	D	E	F
Demand	demand level demand (mgd)	2004 260	2004 260	2004 260	2004 260	2004 260	2030 303	2030 303	2030 303
O'Shaughnessy/Hetch Hetchy	storage volume (KAF)	360	360	0	0	0	0	0	0
Calaveras Reservoir	storage volume (KAF)	97	420\1	420	97	260	260	420	97
Pumps to Calaveras	capacity (cfs)	--	200\2	200	0	200	200	200	0
Sunol Treatment Plant	capacity (mgd)	160	240	400	400	400	400	400	400
Pumps from Don Pedro to Aqueduct	capacity (cfs)	--	--	407	385	407	407	407	407
Groundwater recharge & extraction	storage volume (KAF) recharge capacity (cfs) extraction capacity (cfs)	-- 0 0	-- 0 0	0 0 0	400 200 204	400 200 204	400 200 204	400 200 204	400 200 204

\1 670 KAF facility at $150M is included in CIP, but current thinking suggests SF would build no larger than 420 KAF
\2 Not explicitly included in CIP

[6] These alternatives may involve different combinations of water supply and demand components from those ultimately presented by Environmental Defense

Reservoir to the Hetch Hetchy aqueduct is assumed in all alternatives. Groundwater storage and extraction is examined in five of the alternatives.

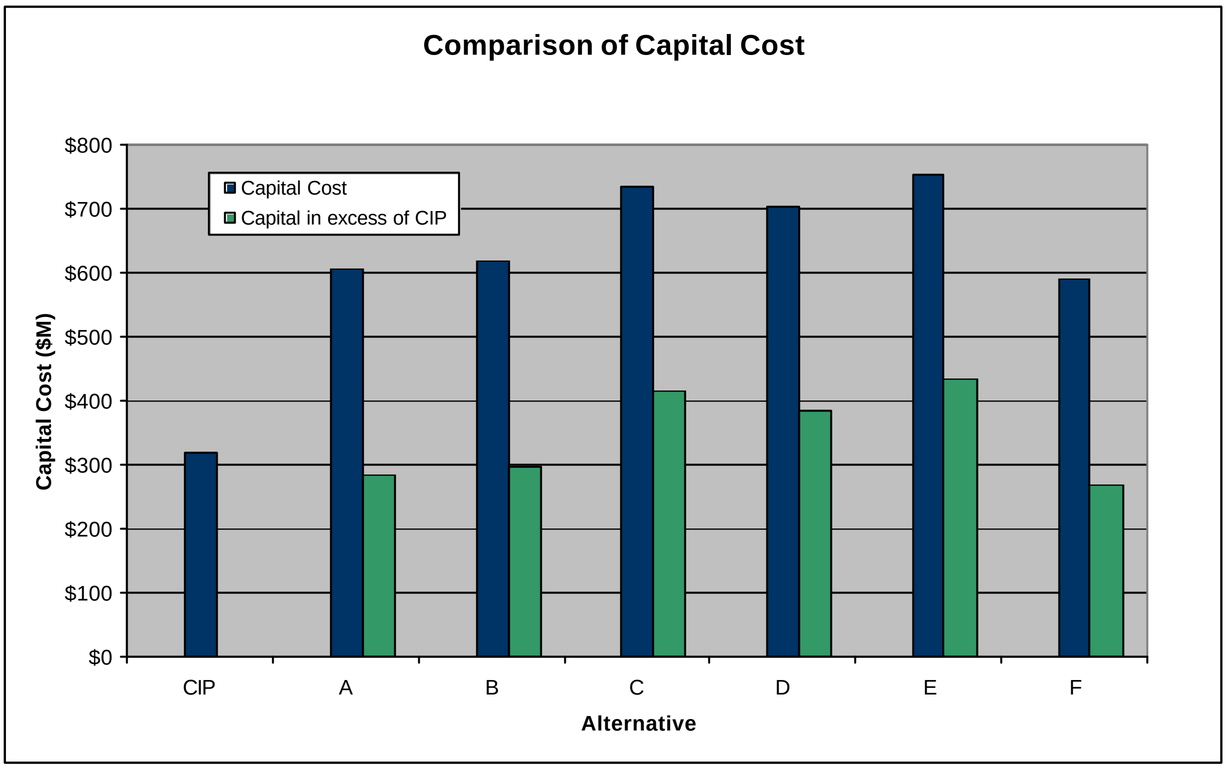
Planning level estimates of capital and annual O&M costs were computed for each alternative applying unit costs to the modeled parameters.

Total capital costs range from $590 million to $750 million.

- The least costly is Alternative F, which uses groundwater storage and the Don Pedro pump-back, but would not enlarge Calaveras Reservoir. Water transfers of up to 12.5 percent are allowed in dry years – transfer costs have not been estimated herein.
- The most costly is Alternative E, which includes both groundwater storage and a 420,000 acre-foot Calaveras Reservoir.

Incremental capital costs in excess of those included in the SFPUC CIP range from $270 million to $430 million. Only CIP facilities integral to the alternative are evaluated.

Operation and maintenance costs average from $4.5 to $7.5 million per year, excluding water treatment costs. Energy costs, estimated at $0.055 per kWh, average from $2.2 to $4.5 million per year, and thus account for half to three-quarters of O&M costs.



Conceptual Cost Estimate of Alternatives for Replacement of Hetch Hetchy Reservoir

06/14/04

			Capital Cost ($M)							
Alternative:	Unit	Unit Cost	Base	CIP	A	B	C	D	E	F
SFPUC CIP Items										
San Joaquin Pipeline #4	LS	$391,380,000.00								
Calaveras Reservoir										
97 KAF	LS	$23,000,000.00	$23.0			$23.0				$23.0
260 KAF	LS	$60,000,000.00					$60.0	$60.0		
420 KAF	LS	$90,000,000.00		$90.0	$90.0				$90.0	
670 KAF	LS\3	$150,000,000.00		/1						
Sunol Treatment Plant										
Base 160 mgd	LS\3									
Expansion	mgd\3	$1,000,000.00		$80.0	$240.0	$240.0	$240.0	$240.0	$240.0	$240.0
Calaveras Reservoir Pumped Storage										
Pipeline\2	dia-in-ft	$7.10		$15.7	$15.7		$15.7	$15.7	$15.7	
Pump station\2	HP	$1,420.00		$27.7	$27.7		$25.2	$25.2	$27.7	
Don Pedro Pumpback										
Intake	LS	$4,000,000.00			$4.0	$4.0	$4.0	$4.0	$4.0	$4.0
Pump station	HP	$1,420.00			$23.1	$23.1	$23.1	$23.1	$23.1	$23.1
Pipeline	dia-in-ft	$7.10			$1.2	$1.2	$1.2	$1.2	$1.2	$1.2
2MG Regulating Basin	cu. yd.	$100.00			$1.1	$1.1	$1.1	$1.1	$1.1	$1.1
Shaft	dia-in-ft	$60.00			$0.4	$0.4	$0.4	$0.4	$0.4	$0.4
Groundwater										
Recharge Ponds	ac	$50,000.00				$20.0	$20.0	$20.0	$20.0	$20.0
Land	ac	$15,000.00				$6.0	$6.0	$6.0	$6.0	$6.0
Trunk Conveyances	ac	$1,600.00				$46.6	$46.6	$34.2	$34.2	$34.2
On-farm distribution	ac	$1,000.00				$29.1	$29.1	$21.4	$21.4	$21.4
1500 gpm extraction wells	ea	$240,000.00				$17.5	$17.5	$17.5	$17.5	$17.5
Unburdened Capital Cost	$M		$23.0	$213.4	$403.2	$411.9	$489.8	$469.8	$502.3	$391.9
Engineering, Legal, Administration	capital cost	20.0%	$4.6	$42.7	$80.6	$82.4	$98.0	$94.0	$100.5	$78.4
Contingency	capital + ELA	25.0%	$6.9	$64.0	$121.0	$123.6	$146.9	$140.9	$150.7	$117.6
Total Capital Cost	$M		$34.5	$320.2	$604.8	$617.9	$734.7	$704.7	$753.5	$587.8
Incremental Capital Cost (vs. CIP)	$M		($285.7)		$284.6	$297.7	$414.6	$384.5	$433.3	$267.7
Capital Recovery (5%, 25 yrs)	$M/yr		$2.4	$22.7	$42.9	$43.8	$52.1	$50.0	$53.5	$41.7

			Operations and Maintenance Cost ($M/yr)							
Alternative:	Unit	Unit Cost	Base	CIP	A	B	C	D	E	F
SFPUC CIP Items										
San Joaquin Pipeline #4	capital cost	0.5%								
Calaveras Reservoir										
97 KAF										
260 KAF										
420 KAF										
670 KAF										
Sunol Treatment Plant										
Base 160 mgd										
Expansion										
Calaveras Reservoir Pumped Storage										
Pipeline	capital cost	0.5%		$0.1	$0.1		$0.1	$0.1	$0.1	
Pump station	capital cost	2.0%		$0.6	$0.6		$0.5	$0.5	$0.6	
Energy	kWh/yr	$0.055		$0.5	$1.1		$0.7	$1.3	$1.5	
Don Pedro Pumpback										
Intake	capital cost	2.0%			$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Pump station	capital cost	2.0%			$0.5	$0.5	$0.5	$0.5	$0.5	$0.5
Trunk Conveyances	capital cost	0.5%			$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2MG Regulating Basin										
Shaft										
Energy	kWh/yr	$0.055			$2.3	$2.1	$2.4	$2.8	$2.7	$2.6
Groundwater										
Recharge Ponds	capital cost	4.0%				$0.8	$0.8	$0.8	$0.8	$0.8
Land										
Trunk Conveyances	capital cost	0.5%				$0.2	$0.2	$0.2	$0.2	$0.2
On-farm distribution	capital cost	0.5%				$0.1	$0.1	$0.1	$0.1	$0.1
Recharge energy	kWh/yr	$0.06				$0.0	$0.0	$0.1	$0.1	$0.1
1500 gpm extraction wells	capital cost	4.0%				$0.7	$0.7	$0.7	$0.7	$0.7
Extraction energy	kWh/yr	$0.055				$0.1	$0.1	$0.2	$0.2	$0.2
Total O&M Cost	$M/yr			$1.1	$4.5	$4.6	$6.3	$7.3	$7.5	$5.2
Total Annualized Cost	$M/yr		$2.4		$47.4	$48.5	$58.4	$57.3	$60.9	$46.9

\1 670 KAF facility at $150M is included in CIP, but current thinking suggests SF would build no larger than 420 KAF
\2 Not explicitly included in CIP
\3 CIP estimates ($81.97M for 80mgd Sunol WTP expansion and $150M for 670KAF Calaveras Reservior) include ~25% allowance for planning, environmental review, design, and construction & project management

CalSim Modeling. Four alternatives were examined where a portion of the SFPUC supply would be released down the Tuolumne River and pumped from the Delta at the State Water Project (SWP) Banks Pumping Plant. Water would be conveyed to the SFPUC service area via an interconnection between the California Aqueduct and the Hetch Hetchy Aqueduct.

This analysis was performed using the CalSim II model of the State Water Project and federal Central Valley Project. The SFPUC water supply system is not included in CalSim, so a new delivery node, aggregate local storage reservoir, and interconnection to the California Aqueduct were added to represent the Bay Area portion of the SFPUC system. SFPUC demands, local inflows, and operations upstream of Don Pedro were generated in Environmental Defense's TREWSSIM model and input into CalSim.

Although portions of the SFPUC water service territory receive water from the SWP, SFPUC does not have the ability to use the SWP facilities. However, additional flows down the Tuolumne River and into the Delta would allow additional Delta exports, and could provide other flow, temperature, and dilution benefits in the river system and Delta. Priority for use of the SWP pumps was set to meet SFPUC demands first, though this results in modeled delivery reductions to SWP and CVP users unlikely to occur in reality. These deficiencies should be used as an index of additional water that would need to be acquired, or as a limitation for this mechanism to supply SFPUC – likely some combination of methods (e.g. Delta pumping plus groundwater banking) would be developed to meet SFPUC needs without injury to other users.

The modeling results indicate that in order to obtain SFPUC delivery reliability comparable to the Baseline alternatives, an average of 75,000 acre-feet per year would need to be pumped from the Delta under current (260 mgd) demands, and about 95,000 acre-feet per year would need to be pumped to meet future (303 mgd) demand levels.

Summary of CalSim II Modeling of Delta Alternatives

Scenario:	2004 Baseline	Delta 1	2020 Baseline	Delta 2	Delta 3	Delta 4
SFPUC delivery objective (mgd)	260	260	303	303	303	303
Calaveras Reservoir capacity (KAF)	97	97	97	260	420	97
San Joaquin Pipelines capacity (mgd)	300	300	350	350	350	350
SFPUC delivery (mgd)	257	257	293	293	293	293
Don Pedro Operations (KAF/yr)						
Inflow	1,520	1,599	1,464	1,578	1,575	1,577
Release	1,463	1,532	1,413	1,512	1,509	1,511
Average Storage (KAF)	1,415	1,593	1,330	1,575	1,575	1,575
MID/TID deliveries	1,108	1,108	1,108	1,108	1,108	1,108
Delta Operations (KAF/yr)						
SWP Banks pumping	3,262	3,303	3,261	3,307	3,311	3,303
SWP delivery	3,047	3,021	3,048	3,011	3,012	2,999
SFPUC delivery	0	75	0	94	95	94
CVP Tracy pumping	2,321	2,321	2,321	2,323	2,321	2,319
CVP delivery	4,765	4,756	4,763	4,754	4,754	4,756
Total delivery (SWP+CVP+SFPUC)	7,812	7,852	7,811	7,859	7,861	7,849
Delta outflow	14,278	14,309	14,232	14,282	14,277	14,291
Difference from Baseline						
Don Pedro releases		69		99	96	98
Net Delivery		40		48	50	38
SFPUC delivery from SWP		75		94	95	94
SWP & CVP deliveries		(35)		(46)	(45)	(56)
Delta outflow		31		50	45	59

Additional releases from Don Pedro would allow increases of net Delta exports (SWP + CVP + SFPUC) of 38,000 to 50,000 acre-feet per year, with alternatives with larger Calaveras Reservoir capacity performing better. Roughly half of the additional release from Don Pedro would leave the system as Delta outflow (with potential environmental benefits).

Technical Memorandum: Summary of Cost Information
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services

May 10, 2004

1. The table below contains unit cost estimates from the Mokelumne Aquifer Recharge and Storage Project 1996 (MARS). Cost estimates have been adjusted from 1995 to 2004 levels using an escalation rate of 4% per year.

Table 8: 2004 Unit Capital Construction Cost

Type of Facility	Unit	Unit Cost
Pump Stations		
0 - 400 HP	HP	$2,850
400 - 800	HP	$2,560
800 - 1,200	HP	$2,280
1,200 - 4,000	HP	$1,990
4,000 - 8,000	HP	$1,820
8,000 - 15,000	HP	$1,610
15,000 - 30,000	HP	$1,420
Pipelines[2]		
54-84" diameter	dia-in-ft	$7.10
84" +	dia-in-ft	$12.10
Tunneling	dia-in-ft	$28.50
Recharge Basin Construction	acre	$50,000
Fish Screen	cfs	$7,100
Injection Wells	each	$360,000
Extraction Wells	each	$240,000
Land	acre	$15,000
Surface Water Treatment Plant[3]	gpd	$1.00

Reference: *Mokelumne Aquifer Recharge and Storage Project*, March 1996

[2]Assume pipelines will not need shoring

[3]Reference: Alternatives for Water Supply from the California Aqueduct (Parsons - February, 2001)

2. In 2002, San Francisco voters passed a $1.6 billion bond to be supplemented by another $2 billion from its suburban customers, to fund a Capital Improvement Program (CIP). The 77 projects that comprise the CIP are intended both to repair the existing San Francisco Public Utility Commission water supply system and to build new and enlarged facilities to accommodate future growth. CIP projects include the following:

    - Calaveras Reservoir Expansion. Project proposes to replace the existing dam with a new dam 200 feet higher that will increase storage from the current 97,000 to up to 670,000 acre-feet. Total cost in 2003 dollars is $150 million for this size reservoir.

Because of faulting and other site constraints (see Calaveras Reservoir tech memo) smaller sizes are also being considered. A 400,000 acre-foot reservoir appears to be the largest that could be constructed with having to build saddle dams across the Calaveras Fault. The SFPUC has not estimated the cost of the smaller reservoirs.

- Fourth Barrel of San Joaquin Pipeline. The new pipeline will be built in SFPUC right-of-way, parallel to existing pipelines. The project will add conveyance capacity and increase flexibility of operations. There are significant system-wide capacity benefits from adding the fourth barrel (see Hydraulics tech memo). The pipeline will be 48 miles long with a design capacity of 130-160 mgd (200-250 cfs). The cost presented in the CIP is $391 million, which is several times higher than costs for similar projects.

  A cost estimate was obtained from Northwest Pipe Company (2004$, without installation) for 48.1 miles of steel pipe is as follows:

Dia	Total	Unit Price ($ per dia-in per ft)
72”	$57.6M	$3.15
84”	$71.7M	$3.36
96”	$90.0M	$3.69

- Sunol Water Treatment Plant Enlargement. The existing Sunol WTP would be expanded from 160 to 240 mgd. The project will include construction of:
  - 2 flocculation/sedimentation basins
  - addition of 6 dual media filters
  - expansion of chemical feed system and chemical tanks
  - mixing and storage facilities
  - modification of wash water recovery systems
  - sludge ponds
  - the addition of a second effluent line
  - embankment excavation and retaining wall construction
  - two emergency generators
  - backwash pump station
  - interface with existing facilities
  - piping, valves, and other mechanical and electrical work

Cost for this 80 mgd expansion is estimated to be $81,974,000 in 2003 dollars (a unit cost of $1.02 per gpd).

- Tunneling Projects included in the SFPUC Capital Improvement Plan:

    - The Irvington Tunnel project will construct a new tunnel with a capacity of 115 to 150 mgd capacity. The $143.9 million estimate for the project assumes construction of a 3.6-mile long, 10.5 foot diameter tunnel parallel to the existing tunnel with isolation valves and cross connections ($7600 per foot, or $60 per dia-in per foot).

    - The Crystal Springs Bypass Tunnel will construct a new 4,200 foot long, 84-inch diameter bypass tunnel, parallel to the existing pipeline. Estimate includes installation of remote controlled isolation valves and cross connection to the existing 84-inch pipeline at cost of $49.5 million ($11,800 per foot, or $140 per dia-in per foot).

  The tunneling costs presented in the CIP are several times higher than costs for similar projects.

3. Additional water treatment capital cost estimates were obtained from several sources.

    - South San Joaquin Irrigation District (Grant Kreinberg, Project Manager). This water treatment plant has received a construction bid of $37.5M for 40MGD immersed membrane ultrafiltration plant ($0.9375/gpd). The plant will use dissolved air pretreatment and Zenon Zeeweed membranes, and a 6-7 million gallon clearwell. The design engineer is Jay Hesey of Black & Veatch. The plant will on 35 acres of a 90 acre campus.

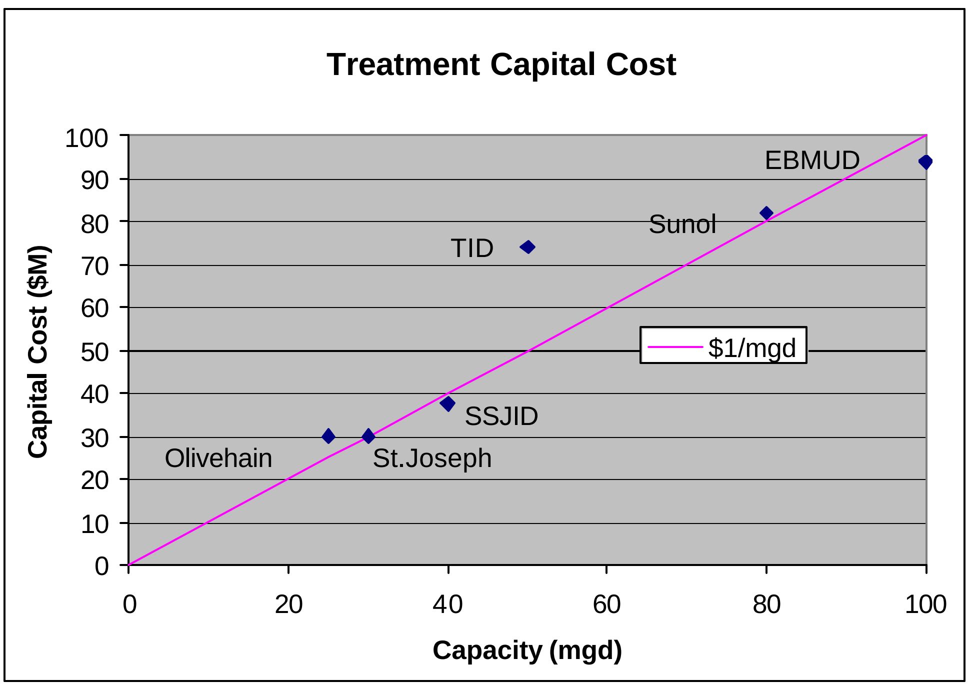
    - Turlock Irrigation District (Dan Madden, City of Turlock Water Resource Manager). Paul Selsky of Brown & Caldwell did the preliminary design of this 50 mgd water treatment plant treating Tuolumne River water. Total project cost $98.3M w/$24.3M in transmission piping ($1.50/gpd). TID will wholesale to up to six agencies, including City of Turlock, whose share is $52M for 13 mgd of capacity, plus an estimated $2M/yr for operation. Current rates for the all-groundwater Turlock water system ($16/mo for unlimited supply) are projected to double even without water treatment plant.

    - EBMUD Freeport Regional Treatment Project (Michael Goldberg, EBMUD). The proposed 100 mgd treatment plant will treat lower Sacramento River water and be sited near Camanche Reservoir. The plant will include a 5 million gallon equalization tank, flocculation basins, sedimentation basins, ozone and ultraviolet treatment, decant basins, an 8 million gallon clearwell and on-site solids handling for an estimated cost of $94 million in 2002 dollars ($0.94 per mgd).

- Olivehain Water Storage Project (Olivehain Municipal Water District, olivehain.com/projects.html). The 25 mgd ultrafiltration treatment plant has an estimated cost of $30M ($1.20/gpd). The current 9 mgd expansion is in the design phase for this plant with an ultimate capacity of 82 MGD ($98 million, $1.20/gpd). Future planned enhancements will add nanofiltration or RO for TDS and hardness removal

- The St. Joseph Missouri Water Treatment Facility (water-technology.net/projects/st_joseph) is a 30 mgd, $30 million ($1.00/gpd) conventional treatment plant with a rapid mix basin, six filters, 1.5 million gallon clearwell, distribution pumping station, and administration facilities.

A capital cost of $1.00 per gallon per day of capacity has been assumed for this study.



4. Planning-level cost estimates were prepared for six alternatives for replacement of Hetch Hetchy Reservoir.

   - Demand level.

   i. Alternatives A, B, and C describe operations at the present (2004) demand level of 260 million gallons per day
   ii. Alternatives D, E, and F describe operations at a projected 2030 demand level of 303 million gallons per day

- The existing Hetch Hetchy conveyance capacity of 350 mgd was used for all alternatives. Additional capacity may be available if the fourth barrel of the San Joaquin Pipelines is added as part of the SFPUC CIP, but this capacity is not necessary for the alternatives studied.

- Calaveras Reservoir
   i. Calaveras Reservoir enlarged to 260,000 acre-feet is included in Alternatives C and D.
   ii. Calaveras Reservoir enlarged to 420,000 acre-feet is included in Alternatives A and E.

   iii. A 200 cfs pumping facility from the Alameda Creek Siphons to Calaveras Reservoir is included in Alternatives A, C, D and E.

   iv. The model constrains Calaveras releases to 200 cfs, but the release capability would be significantly greater that this.

- Sunol Water Treatment Plant enlarged to a capacity of 400 mgd is included in all alternatives. The present 160 mgd plant would be expanded to 240 mgd as part of the SFPUC CIP.

- The capability to pump 400 cfs from Don Pedro Reservoir to the Foothill Tunnel is included in all Alternatives.

- Groundwater storage in the San Joaquin Valley is included in Alternatives B, C, D, E, and F.

   i. Up to 200 cfs would be recharged via infiltration ponds

   ii. Additional amounts of surface water would be provided to current groundwater users in-lieu of their pumping.
      1. Up to 386 cfs (23,300 acre-feet per month) would be provided in-lieu in Alternatives B and C.
      2. Up to 283 cfs (17,100 acre-feet per month) would be provided in-lieu in Alternatives D, E, and F.

   iii. In dry years, up to 200 cfs of stored water would be extracted and provided to surface water users in MID and TID. A like amount of MID and TID Tuolumne River entitlements are assumed to be made available for San Francisco's use.

5. A summary of model input and output parameters is tabulated below.

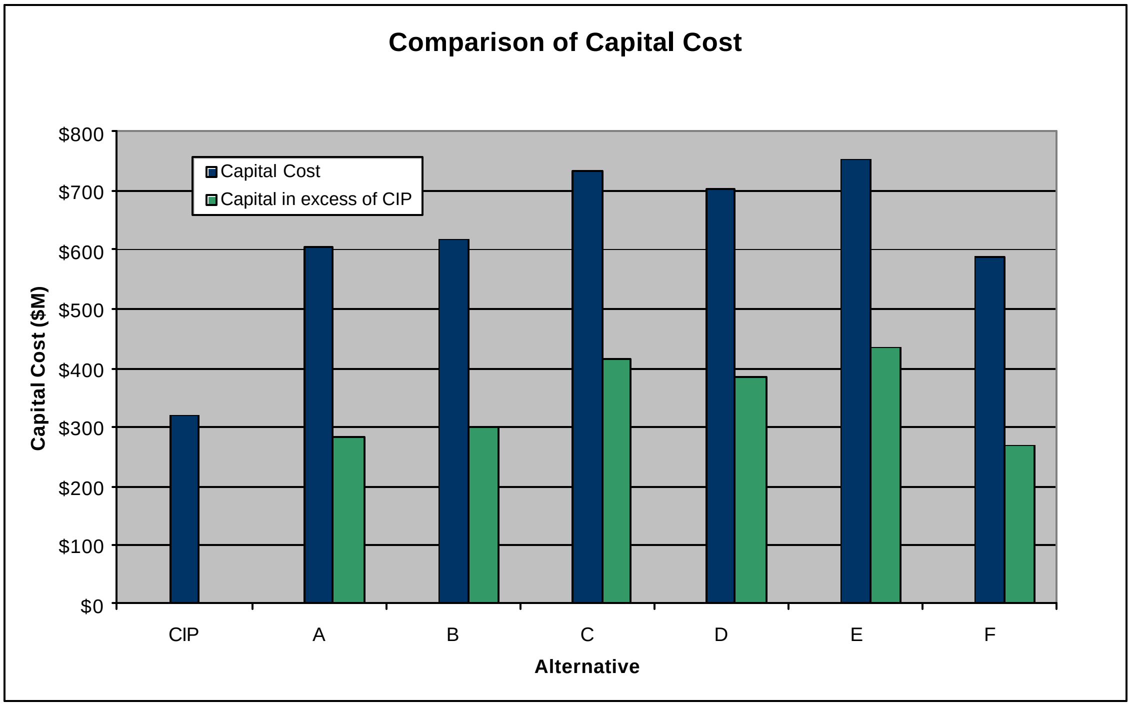
Model Input and Output Parameters for Hetch Hetchy Reservoir Replacement Scenarios

	Alternative:	Base	CIP	A	B	C	D	E	F
Demand	demand level	2004	2004	2004	2004	2004	2030	2030	2030
	demand (mgd)	260	260	260	260	260	303	303	303
	average demand (KAF/yr)	291	291	291	291	291	340	340	340
	demand met (KAF/yr)	288	--	288	288	291	339	340	339
O'Shaughnessy/Hetch Hetchy	storage volume (KAF)	360	360	0	0	0	0	0	0
San Joaquin Pipeline	number of pipelines	3	4	3	3	3	3	3	3
	peak flow[3] (cfs)			542	542	542	542	542	542
	average volume (KAF/yr)	259	259	272	257	269	315	319	306
Calaveras Reservoir	storage volume (KAF)	97	420[1]	420	97	260	260	420	97
Pumps to Calaveras	design size (cfs)	--	200[2]	200	0	200	200	200	0
	peak flow (cfs)	--	--	204	0	197	204	204	0
	pump lift (TDH, ft)	--	602	602	462	547	547	602	462
	average volume (KAF/yr)	--	--	22	0	17	29	31	0
	release to SWTP (KAF/yr)	--	--	14	10	12	32	34	22
Sunol Treatment Plant	peak flow (mgd)	160	240	400	400	400	400	400	400
	average volume (KAF/yr)	--	--	244	249	245	300	303	304
Pumps from Don Pedro to Aqueduct	peak flow (cfs)	--	--	407	385	407	407	407	407
	average volume (KAF/yr)	--	--	112	102	118	141	136	130
Groundwater recharge & extraction	storage volume (KAF)	--	--	0	400	400	400	400	400
	peak direct recharge (cfs)	0	0	0	200	200	200	200	200
	peak total recharge (cfs)	0	0	0	586	586	483	483	483
	avg recharge volume (KAF/yr)	0	0	0	13	15	20	21	18
	peak extraction (cfs)	0	0	0	204	204	204	204	204
	avg extraction volume (KAF/yr)	0	0	0	10	13	19	20	17

\1 670 KAF facility at $150M is included in CIP, but current thinking suggests SF would build no larger than 420 KAF
\2 Not explicitly included in CIP
\3 Capacity imposed in model -- facilities may convey more depending on head conditions

6. Planning level estimates of capital and annual O&M costs were computed for each Alternative applying the unit costs described above to the modeled parameters.
   - Total capital costs range from $590 million to $750 million.
      i. The least costly is Alternative F, which uses groundwater storage and the Don Pedro pump-back, but would not enlarge Calaveras Reservoir. Water transfers of up to 12.5 percent are allowed in dry years – transfer costs have not been estimated herein.
      ii. The most costly is Alternative E, which includes both groundwater storage and a 420,000 acre-foot Calaveras Reservoir.
   - Incremental capital costs in excess of those included in the SFPUC CIP range from $270 million to $430 million.

- Operation and maintenance costs average from $4.7 to $7.6 million per year, excluding water treatment costs. Energy costs, estimated at $0.055 per kWh, average from $2.2 to 4.5 million per year, and thus account for half to three-quarters of O&M costs.



Technical Memorandum: Calaveras Reservoir Pumped Storage
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services
April 22, 2004

1. Based on the information collected from the files at the Department of Water Resources Division of Safety of Dams (DSOD), the current conceptual designs and engineering restrictions are being considered at Calaveras Dam. As of December 10, 2003, the preliminary project alternatives are as follows:

   a. Repair or replace dam for the same reservoir storage – crest elevation 779 feet[7], storage 96,850 acre-feet

   b. Repair or replace dam for increased reservoir storage – crest elevation 900 feet, storage up to 420,000 acre-feet

   c. Repair or replace dam for the same storage with provisions for future enlargement – crest elevation up to 900 feet, storage up to 420,000 acre feet

2. The proposed maximum reservoir surface elevation of 900 feet was determined for a dam design that does not require the construction of saddle dams. This reservoir surface elevation would provide a maximum storage of 420,000 acre-feet. A reservoir surface elevation above 900 feet would require a saddle dam across the active Calaveras fault, and DSOD has recommended against this design.

3. Currently, the preferred location for a replacement dam is immediately downstream of the existing dam. This location offers a relatively narrow canyon providing shallow bedrock abutments thus allowing a dam design with a short axis length. This location would also allow for the existing Calaveras Dam to operate as a cofferdam during construction, thus allowing San Francisco PUD critical water storage at the currently restricted elevation of 705 feet. It should be noted that the downstream location is actually limited to a narrow footprint by a deep-seated landslide downstream of the proposed right abutment, and would require a steep-sided dam.

4. An additional location being considered for a replacement dam includes an alignment immediately upstream of the existing dam. This location would allow for a wide earth and rockfill dam but would require a lengthy dam axis to key into the distantly spaced bedrock abutments. Such a lengthy dam design could prove costly. This location would also require draining Calaveras Reservoir for construction, therefore reducing San Francisco PUC's water supply.

[7] All elevations are reported using the USGS datum.

5. Construction options being considered for a replacement dam consist of:

    a. Concrete-faced rockfill - According to a conversation with Jim Lessman (DSOD), this alternative offers the steep-sided dam design required for the limited footprint in which a dam can be constructed at the preferred location. Jim Lessman also noted that a preliminary evaluation of local borrow materials indicated that there would not be adequate rockfill nearby, thus this design option would require the costly import of rockfill construction material.

    b. Roller Compacted Concrete (RCC) – A rigid RCC dam will likely not be recommended as a final alternative for this site due to the proximity of active faults.

    c. Earth and rockfill – This construction alternative is attractive based on cost and availability of local borrow materials, but would require a larger footprint than a concrete-faced rockfill design, that could also prove costly.

6. Calaveras Reservoir is located at the confluence of Calaveras Creek and Arroyo Hondo. Flows released from the reservoir to Alameda Creek flow northerly through the Sunol Valley before turning westerly through Niles Canyon and the City of Fremont where it discharges to San Francisco Bay. Alameda Creek crosses the Hetch Hetchy Coast Range Tunnel approximately five miles downstream of Calaveras Reservoir. Approximately midway in the Coast Range Tunnel, the creek is crossed by the Alameda Creek Siphons, three steel pipelines with a design capacity of 546 cfs (353 mgd).

7. Calaveras Reservoir can also impound flows from Upper Alameda Creek, diverted at Upper Alameda Creek Diversion Dam through the 650 cfs (420 mgd) Upper Alameda Tunnel. The diversion dam has an overflow elevation of 900 feet. The highest outlet from this diversion is at elevation 888 feet. Inflow to an enlarged Calaveras Reservoir would thus be restricted at high reservoir elevations.

8. Historically, the SFPUC has operated groundwater infiltration galleries in the Sunol Valley, and pumped groundwater from its Pleasanton wellfield. The current status of these facilities was not verified for this study.

9. The elevation of the Coast Range Tunnel at Alameda Creek is about 330 feet. A static pumping lift of 570 feet would thus be required to lift Hetch Hetchy water to an enlarged Calaveras Reservoir.

10. Calaveras Reservoir is connected to the Alameda Creek Siphons through a 30,748-foot, mostly 44-inch diameter steel pipeline. The gravity-flow capacity of this pipeline is listed as 121 cfs (78 mgd) assuming the present reservoir elevations, operation of an aerator, and a hydraulic grade line of 370 feet in the

Coast Range Tunnel. These parameters equate to a Manning's "n" roughness value of about 0.0137, which exceeds values expected for steel pipe. Velocities at maximum flow would be a very high 11.5 feet per second.

11. Assuming a maximum velocity of 7 feet per second to pump water to an enlarged reservoir through the existing pipeline, approximately 74 cfs (48 mgd) could be lifted using a 8500 horsepower pumping plant operating at 70 percent efficiency. This assumes that the existing pipeline could withstand the additional 110 psi pressure that the higher reservoir would create. (570' static + 143' friction)

12. The projected operating scenario for the alternatives calls for moving as much as 17,000 acre-feet per month (282 cfs or 182 mgd) into Calaveras Reservoir from the Hetch Hetchy system. Assuming a maximum velocity of 7 feet per second, and a roughness value of 0.0100 typical of steel, an 84-inch diameter pipeline and 28,000 horsepower pumping plant would be required. (570' static + 35' friction). The gravity flow capacity of this pipeline would be about 1120 cfs (724 mgd or 68,000 acre-feet per month), far exceeding the downstream demand or conveyance capacity.

13. Using unit costs of $6.10 per diameter-inch per foot for pipeline and $1710 per horsepower, minimum capital costs of about $63 million would result from diameters from 78 to 90 inches, although upsizing to 120-inch pipe would only add $4 million. The most economic design should be selected based on expected operating costs.

14. Improvement of Calaveras Reservoir is included as a high priority project in the SFPUC Capital Improvement Program. Improvements have a baseline cost of $150 million[8] for a 670,000 acre-foot reservoir. Detailed costs estimates for smaller reservoirs are not available. A simple analysis of reservoir volume suggests a 260,000 acre-foot reservoir would require a 315-foot-high dam. A 420,000 acre-foot reservoir would require an approximately 370-foot-high dam. Assuming the volume of embankment material for the dam is proportional to the cube of the height, and that construction cost is proportional to dam volume, capital cost for the 260,000 acre-foot reservoir would be about $60 million, and the 420,000 acre-foot reservoir would be about $90 million.

15. A new treated water reservoir at the Sunol Valley Water Treatment Plant is included as a high priority project in the SFPUC Capital Improvement Program. Improvements have a forecast cost of $48.8M[9]. The project is scheduled for completion in November 2007.

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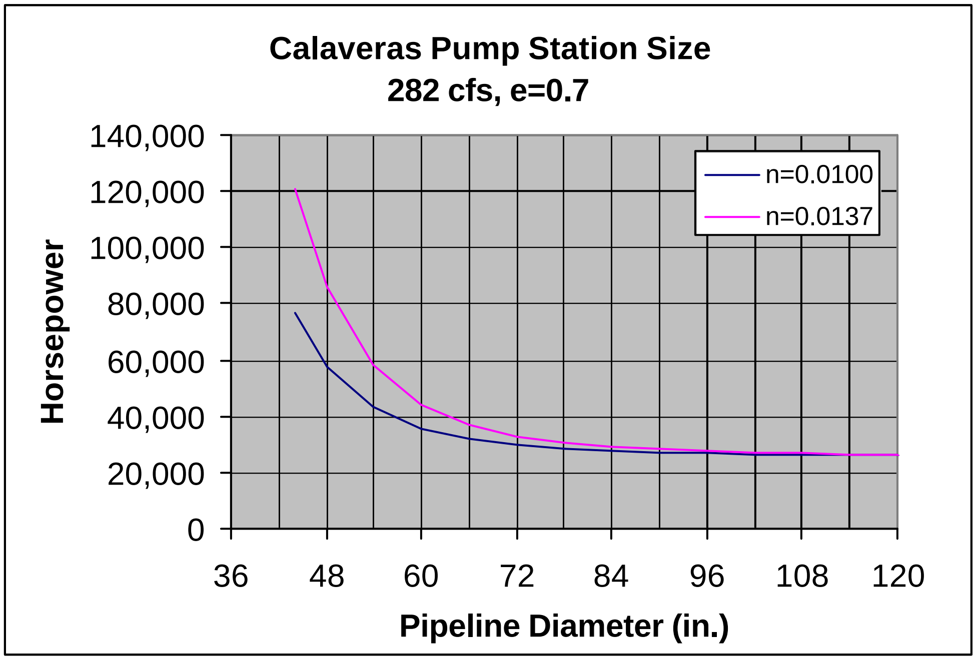
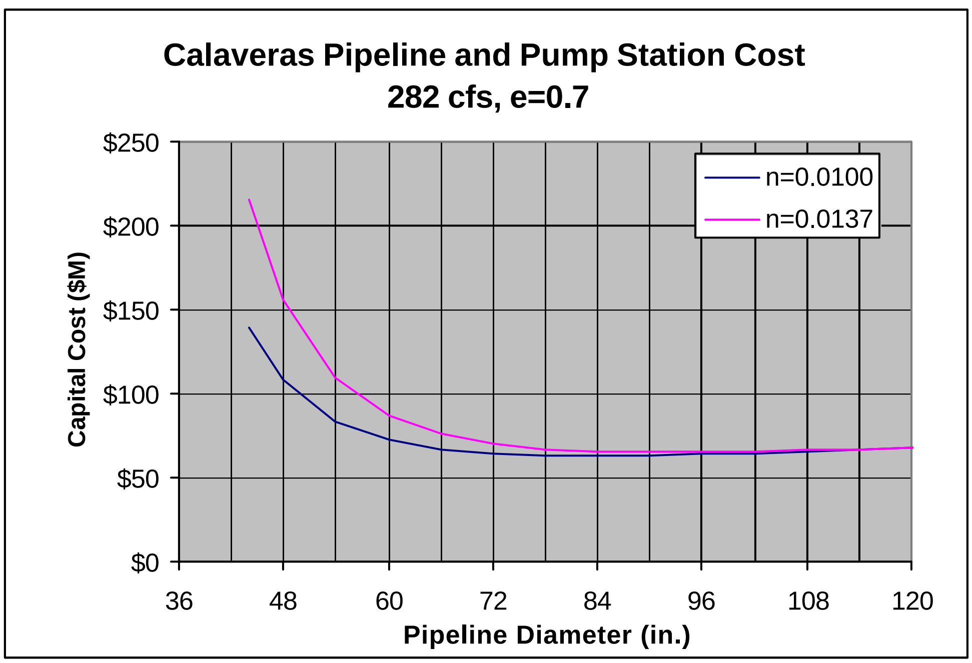
[8] Presentation by Harlan L. Kelly, Jr., SFPUC Infrastructure AGM, December 1, 2003
[9] ibid.


Calaveras Pump Station Size
282 cfs, e=0.7
Horsepower
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
36
48
60
72
84
96
108
120
Pipeline Diameter (in.)
n=0.0100
n=0.0137


Calaveras Pipeline and Pump Station Cost
282 cfs, e=0.7
Capital Cost ($M)
$250
$200
$150
$100
$50
$0
36
48
60
72
84
96
108
120
Pipeline Diameter (in.)
n=0.0100
n=0.0137

Technical Memorandum: Don Pedro Pumpback
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services
April 13, 2004

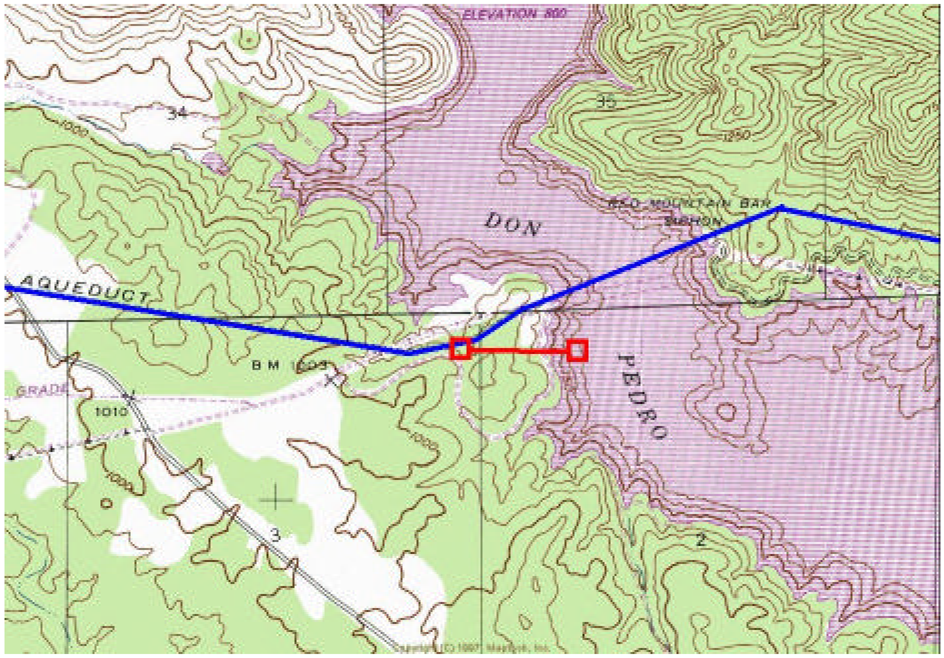
1. The Hetch Hetchy Aqueduct crosses under Don Pedro Reservoir at Red Mountain Bar Siphon. The USGS reports Don Pedro water surface (i.e. spillway) elevation as 800 feet (244 meters). The dam crest elevation is 855 feet.

2. The Aqueduct at about 840 feet elevation on either side of the 9.5-foot diameter, 2500-foot-long Red Mountain Bar Siphon. The design capacity of the siphon is 620 cfs (400 mgd). The invert elevation at the siphon low point is at about 517 feet. There is an 80-foot-high standpipe at the east end of the siphon with an overflow elevation of 930 feet. There is a wasteway overflow shaft at the west end of the siphon with an overflow elevation of 860 feet.

3. Two means of pumping water from Don Pedro Reservoir are considered:

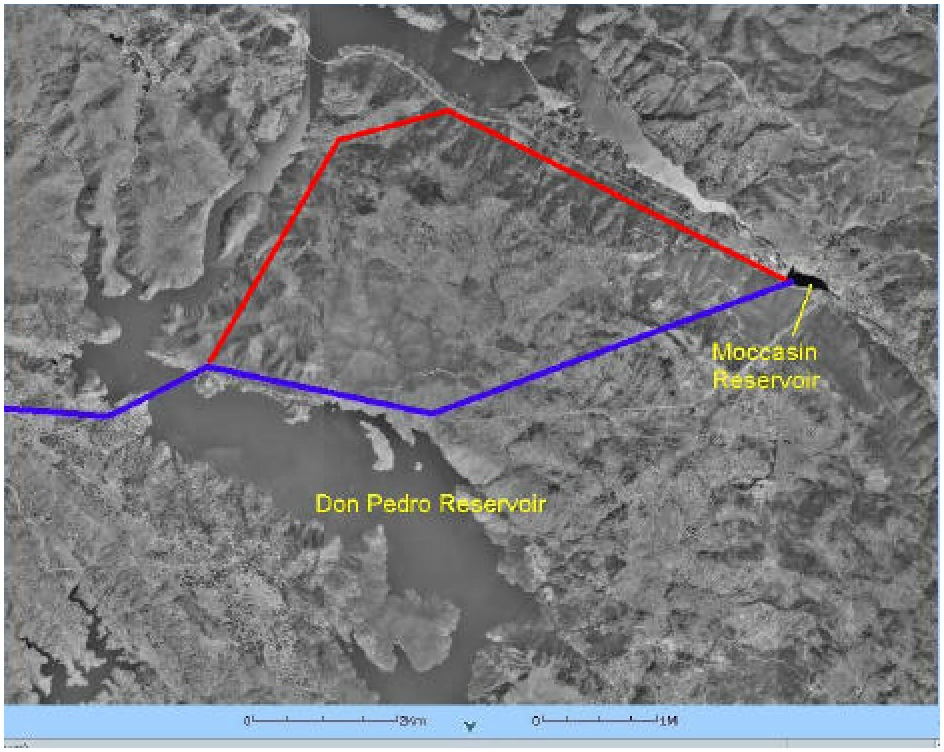
    a. Pumping into the Foothill Tunnel through a vertical shaft. The land rises rapidly on both sides of the Reservoir where a shaft could be located. A top elevation of about 900 feet would be compatible with the hydraulic gradeline of the aqueduct.

       For this analysis, a pumping plant at the west end of Red Mountain Bar Siphon would deliver water to a regulating basin and vertical shaft connected to the Foothill Tunnel.



b. Pumping from Don Pedro back to Moccasin Reservoir. A direct route following the Hetch Hetchy powerline right of way would need to traverse a 2300-foot-high saddle between Moccasin Peak and Domingo Peak, most practically by tunneling. A longer route along the periphery of the reservoir would require construction in steep terrain. A tunnel paralleling the Foothill Tunnel is likely the most practical route.

   For this analysis, a pumping plant at the east end of the Red Mountain Bar Siphon would pump water to a tunnel with an inlet at elevation 970 feet that would convey water by gravity to Moccasin Reservoir.


Moccasin
Reservoir
Don Pedro Reservoir

Technical Memorandum: Groundwater Banking
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services
April 30, 2004

16. This Tech Memo focuses on groundwater banking in the area downstream of Don Pedro Reservoir, principally in Modesto Irrigation District, Turlock Irrigation District, or the Eastside Water District. In addition to taking its Tuolumne River water rights from Early Intake and from proposed facilities to divert from Don Pedro, MID and TID water needs might be supplied by SFPUC from banked groundwater in dry years in exchange for MID or TID surface water supplies.

17. A number of potential sites for groundwater banking of SFPUC Tuolumne River water have been identified, including in the San Joaquin Valley, Sunol Valley, Westside Groundwater Basin on the Peninsula, and in Hetch Hetchy Valley.

18. Hetch Hetchy Water and Power commissioned a 1993 that examined more than 15 groundwater banking alternatives, plus a number of purchase and transfer opportunities[10]. Notably absent in the HHWP study is banking in the Modesto and Turlock Irrigation Districts, and in the Hetch Hetchy Valley. Banking in the Eastside Water District is summarized as "ideal for Hetch Hetchy" but is ranked as a "fair" opportunity because of institutional complexity. Locations ranked as "good" opportunities include:
    - Livermore Valley
    - Western San Joaquin County
    - Northern San Benito County
    - Madera Ranch
    - Semitropic Water Storage District
    - James Irrigation District/Mid-Valley Water District vicinity
    - Kern Fan Element

    Purchase of water from the Oakdale and South San Joaquin Irrigation Districts is ranked as a "good" opportunity.

19. The 1993 HHWP Groundwater Banking study provides the following information on the Sunol Valley:

    a. The geology consists of a thin (50 feet or less) layer of alluvium with high water yielding characteristics, underlain by thicker (400 feet plus) older Livermore Gravels that are more compacted and contain a clay matrix

[10] City and County of San Francisco Hetch Hetchy Water and Power, Reconnaissance Evaluation of Alternative Sites for Groundwater Banking, Bookman-Edmonston Engineering Inc, and Luhdorff and Scalmanini Consulting Engineers, unpublished work July 1993

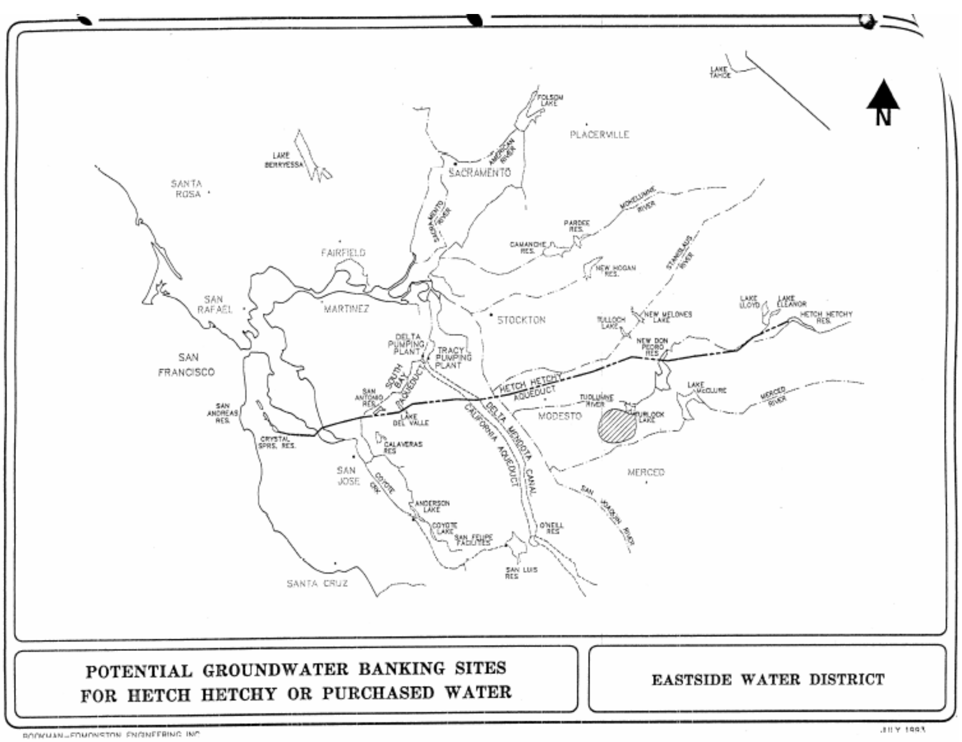
which reduces water holding and yielding characteristics. Active storage potential in the upper alluvium is estimated as about 2500 acre-feet.

b. Planned and current gravel mining operations are removing potions of the Valley's groundwater storage capacity. The played-out mining pits have the potential for 30,000 to 50,000 acre-feet of water storage in the future. (A project to convert six mining pits into storage reservoirs is included in the SFPUC's CIP.)

20. The 1993 HHWP Groundwater Banking study provides the following information on the Eastside Water District (ESWD):

a. ESWD is located on the eastern side of the San Joaquin Valley near the Stanislaus and Merced County line. The land is gently westward sloping alluvial plains bordering the edge of the Sierra Nevada grading out to the San Joaquin River. The area is agricultural and is sparsely populated.

b. The Corcoran Clay occurs just west of the area which confines the lower aquifer units. The geologic units are coarse-grained sands and gravels with interbedded thin silts and clays.



Source: SFPUC, 1993

c. ESWD has an agricultural economy based entirely on groundwater. Extractions exceed the natural supply and groundwater levels have declined significantly.

d. San Francisco's groundwater modeling efforts in the area[11] show EWD overdraft as about 50,000 acre-feet per year. Cumulative overdraft since 1970 is estimated as 1,000,000 acre-feet, of which one-quarter directly underlies EWD.

21. Modesto Irrigation District (MID) is comprised of 64,121 acres within a 101,683 acre territory. Tuolumne River water is conveyed through 208 miles of canals and pipelines to 3400 irrigation customers. Water is regulated by Don Pedro Reservoir and diverted to MID and TID at La Grange Dam. MID water is reregulated in the 28,000 acre-foot Modesto Reservoir. An average of 192,841 acre-feet of water is delivered at a current annual cost of $11.10 per acre. MID also wholesales water treated at the 30 MGD Modesto Regional Water Treatment Plant to the City of Modesto.[12] The treatment plant is planned to be expanded to 60 MGD[13]. A 67,200 acre-foot per year water right transfer from MID to Modesto was filed on January 8, 2004.

22. Turlock Irrigation District (TID) imports approximately 435,000 acre-feet per year of surface water from Don Pedro Reservoir for agricultural irrigation. TID also supplements its surface water supply with groundwater. The amount of groundwater pumped by TID varies from year to year depending on the availability of surface water and irrigation requirements. The average groundwater use for 1984-96 was 106,000 acre-feet per year[14]. TID pumps groundwater into a series of canals for distribution to users within its service district. Some individual growers within TID pump groundwater to augment their surface water allotment from TID while other growers rely exclusively on groundwater. Based on electrical power usage, groundwater extractions by individual growers in the TID service area are estimated to be approximately 123,000 acre-feet per year.

23. Eastside Water District (ESWD) currently uses groundwater as a source for the majority of its supply within its service district except for small amounts of surface water delivered by TID and MID during wet years. Irrigation water for agriculture is supplied by wells located throughout the ESWD. The average annual water requirement is approximately 155,000 acre-feet.

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[11] The referenced modeling has not been found.
[12] http://www.phillipsdesign.com/mid/html/fngr_fax.htm
[13] The Modesto Irrigation District Annual Report that groundwater supplies about 45 million gallons per day (50,000 acre-feet per year) of water supply to the City of Modesto, which is about 60% of its needs. The remaining 40%, about 30 MGD, is supplied by the Modesto Regional Water Treatment Plant, which was constructed in 1994. A long-term forecast of demand (details not provided) showed that the treatment plant would need to be enlarged by 2005
[14] A spreadsheet dated March 19, 2004 obtained from TID shows groundwater pumping from 1999 through 2003 ranged from 7281 to 42,207 acre-feet, and averaged 20,319 acre-feet per year

24. MID, TID, and EWD are is located in the northeastern portion of the San Joaquin Valley near the center of the Central Valley geomorphic province. The eastern boundary of the basin is the western extent of the outcrop in the foothills of the Sierra Nevada known as the Valley Springs Formation. The City of Turlock's Groundwater Management Plan[15] provides the following information:

Geology and Groundwater Occurrence

a. The regional terrain is a low relief plain that was formed by coalescing alluvial fans. Most of the basin is underlain by unconsolidated Pleistocene to Holocene alluvium (Qoa) that consists of interbedded layers of clay, silt, sand and gravel. Sand and gravel deposits were deposited in the stream channels of alluvial fans and are elongated and lenticular. Silt and sand were deposited between the stream channels by overbank flows and are found in sheet-like layers. Silt and clay were deposited in lakes and marshy lowlands. Most of the clay layers are laterally discontinuous except for the E-clay (also known as the Corcoran clay).

b. The E-clay is a continuous blue to gray silty clay layer of low permeability that occurs in the middle of the older alluvium (Qoa). The thickness of the E-clay is generally reported to vary from 30 to 60 feet in the area.

c. Older Pliocene to Pleistocene (QTc) unconsolidated alluvium deposits underlay the Qoa alluvium. The QTc alluvium is similar to the Qoa alluvium but is finer grained. The base of the Qoa alluvium is arbitrarily defined as occurring at depths where well driller's logs indicate a change from course-grained to fine-grained sediments. Figure 2.2 (Page & Baldwin, 1973) shows a geologic cross section through the area.

d. Beneath the unconsolidated Qoa and QTc alluvium are Upper Cretaceous marine shales that contain high salinity groundwater.

e. Groundwater in the area occurs as: (1) fresh groundwater above the E-clay, (2) fresh groundwater in the alluvial aquifer beneath the E-clay, and (3) saline groundwater in the older marine sediments beneath the fresh water. Groundwater is generally unconfined above the E-clay and confined under the E-clay. Groundwater above the E-clay may be semiconfined at depth due to the cumulative presence of various confining layers of silt and clay. In the eastern regions of the basin where the E-clay does not exist, fresh groundwater is unconfined.

f. A significant source of recharge for the upper aquifer is through excess applied irrigation water that percolates past the root zone. The Turlock

[15] City of Turlock Groundwater Management Plan, Saracino-Kirby, Inc with Harding Lawson Associates, January 2000

Irrigation District (TID) annually imports approximately 435,000 acre-feet of surface water into the basin for agricultural irrigation purposes. Recharge to the confined aquifer below the E-clay is through interflow from the unconfined water body upgradient of the extent of the E-clay and, to a limited amount, through movement of water through the E-clay when and where the pressure gradient allows. Subsurface inflow to the basin and rainfall (11 in/yr.) are relatively minor sources of recharge. Groundwater extractions for agricultural, municipal and industrial uses represent the primary cause of discharge of groundwater from the basin. Extractions from the basin currently exceed recharge by approximately 70,000 to 85,000 acre-feet per year.

g. Natural groundwater movement in the Turlock area above and below the E-clay is generally westward toward the valley trough. In the unconfined aquifer the water also moves toward the major rivers and toward pumping depressions.

h. Due to its low permeability, the E-clay transmits little water and the rate of this water movement is slow relative to that in adjacent alluvium. The direction of movement through the E-clay (either up or down) is determined by the hydraulic gradient, which is a function of natural hydrostatic pressure and pumping-induced pressure changes.

i. High water levels that exist in the unconfined aquifer in the western portion of the basin are due to infiltration of surface water applied for agricultural irrigation. Due to the relatively low permeability of the E-clay, applied irrigation water that percolates past the root zone accumulates in the unconfined aquifer and results in a high water table in the upper aquifer. The water levels fluctuate from year to year and over the course of the irrigation season as a result of pumping, precipitation, and applied irrigation water.

j. In the western area of the area, dewatering pumps operated by the Turlock Irrigation District move the high groundwater to irrigation canals to minimize adverse impacts to crops. TID owns and operates approximately 170 drainage wells in their service area. Subsurface drains have also been utilized to control groundwater levels. Water that is pumped to control drainage problems is usually discharged into the TID irrigation canal system where it is distributed for irrigation purposes.

k. Groundwater in the basin contains dissolved and suspended substances. Some are naturally occurring and some have been introduced through human activities. The majority of the substances do not impact beneficial uses of the water. Generally, water quality is poorer in the upper, unconfined aquifer. Nitrates, pesticides, solvents and other constituents introduced at the surface are carried downward into the upper aquifer by recharge. These constituents can be drawn into the lower confined aquifer through improperly constructed wells, abandoned wells, damaged wells, wells that are screened both above and below the E-clay and to a small degree, from downward movement through the E-clay.

Other Groundwater Users

l. The basin is utilized by a number of cities, water districts, irrigation districts, and community service districts. Nine major urban water utilities pump approximately 36,200 acre-feet of groundwater per year (1995 data). Well depths range from 100 to 600 feet below ground surface.

m. Approximately 180 small water systems are located in the basin. A small water system is defined as one that serves 5 or more but less than 200 connections. An estimated additional 10,900 acre-feet per of groundwater per year is pumped by small private residential water systems and commercial and industrial operations not served by the major utilities.

n. Within the basin, approximately 47% of the total annual agricultural irrigation demand (410,000 acre-feet) is met with groundwater. The remaining 53% (470,000 acre-feet) is met with surface water supplies, primarily from the Tuolumne and Merced rivers.

o. The City of Modesto has relied on groundwater for supplies in its service area that lies south of the Tuolumne River and within the groundwater basin utilized by Turlock. This area is not interconnected with the rest of Modesto's water system located north of the Tuolumne River. A pumping depression exists in the City of Modesto due to groundwater withdrawals by the city to meet municipal and industrial (M&I) needs in their service area. The cone of depression had enlarged to reach the town of Ceres. This cone of depression has been reduced significantly since Modesto began using nine million gallons per day (mgd) of surface water.

p. Other municipalities that provide Turlock basin groundwater to customers include the cities of Ceres, Hughson, Denair, Keyes, Hilmar, and Delhi.

q. The Ballico-Cortez Water District has limited access to surface water supplies for irrigation purposes and relies on groundwater to meet the majority of its annual needs of approximately 27,000 acre-feet.

r. The City of Turlock relies on groundwater to supply the needs of its residential, commercial and industrial customers. Wells owned by other entities have supplied, and some continue to supply, groundwater to Turlock. The City's water system consists of 23 wells with a combined pumping capacity of 22,000 gallons per minute. Well depths range from

244 to 610 feet below ground surface. All of the City's wells penetrate the E-clay. Although some wells are screened in the aquifer above the E-clay, the majority of City wells are screened in the confined aquifer located beneath the E-clay.

25. DWR Bulletin 118-2003 states that the well yields in the Modesto and Turlock groundwater average 1,000-2,000 gpm with some wells producing up to 4500 gpm.

26. Only surface (pond) groundwater recharge is considered herein. Injection wells are generally considered more expensive to operate because of pretreatment requirements, but might be feasible in the MID/TID area for the following reasons:

    a. Injection wells will allow recharging the confined aquifer beneath the Corcoran Clay.
    b. The high quality of the Tuolumne River water could allow for rejection without pretreatment. Pilot testing in San Joaquin County[16] with comparable-quality Mokelumne River water successfully demonstrated the feasibility of recharging untreated water, provided the system is operated to maximize input water quality[17]

27. Annual groundwater use in the Turlock Groundwater Basin[18] is estimated[19] to be 411,000 acre-feet per year, 47 percent of total water usage. Peak agricultural water use occurs in the months of June, July and August, which accounts for an estimated 60 percent of total agricultural groundwater use[20]. Water use by crop varies, but applied groundwater is typically 4 acre-feet per acre.

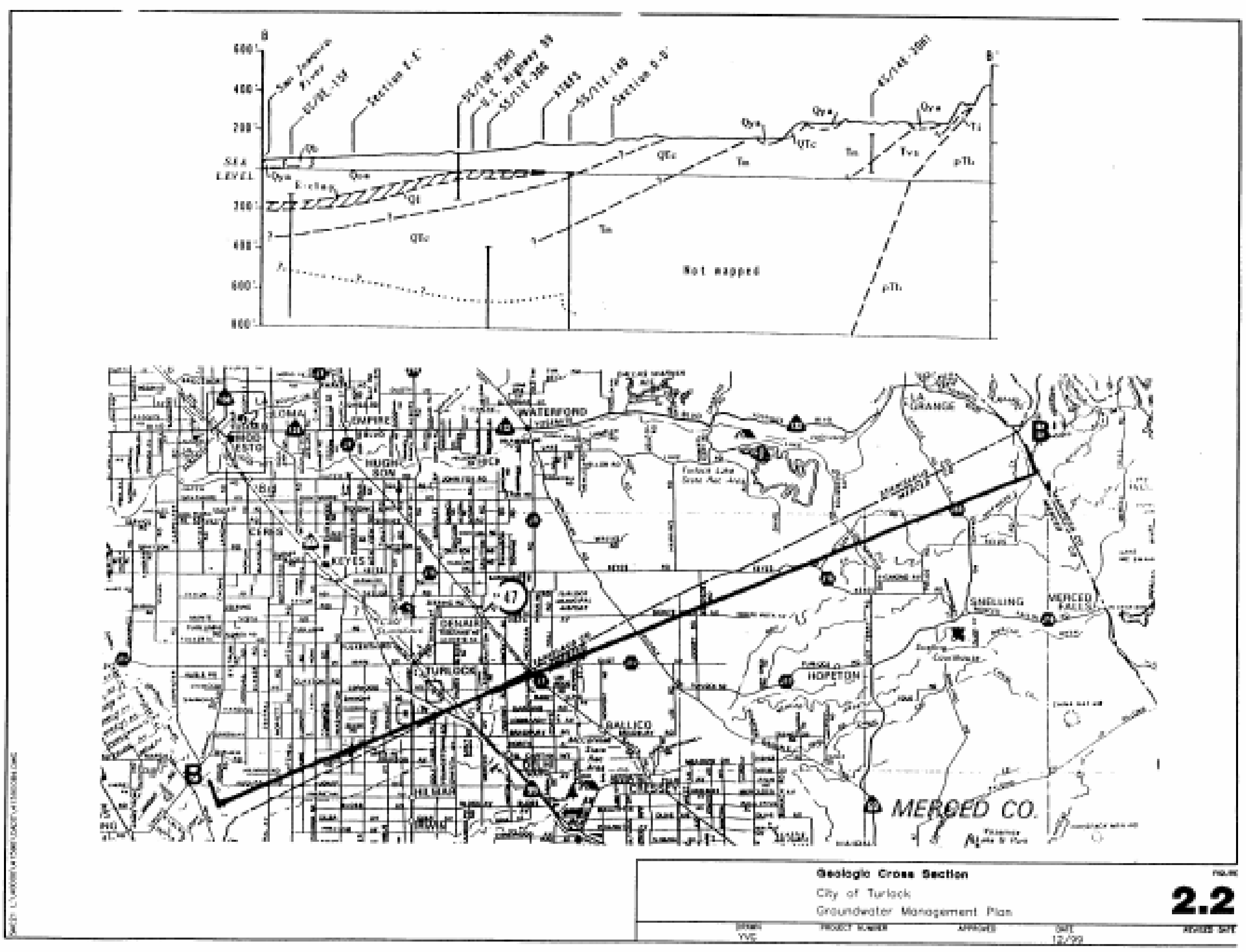
28. The modeled capacity of the groundwater recharge ponds is 200 cfs (145,000 acre-feet per year). The highest direct recharge modeled in any alternative averages 21,000 acre-feet per year (14 percent of capacity). This low utilization rate would allow adequate down time for pond maintenance. Consequently, no additional capacity has been estimated for peaking or maintenance.

29. The modeled capacity of in-lieu recharge is 386 cfs (23,300 acre-feet per month) for Alternatives B and C, and 283 cfs (17,100 acre-feet per month) for Alternatives D, E, and F. Using the 20 percent peak month for 4 acre-foot per acre typical crop water needs, approximately 29,100 participating in-lieu acres

[16] East San Joaquin Parties Water Authority and EBMUD, 1999
[17] For this test, water injection was halted whenever influent water quality exceeded 2 NTU (nephelometric turbidity units)
[18] Includes Turlock Irrigation District, individual growers within TID, Eastside Water District, and Ballico-Cortez Water District
[19] Turlock Irrigation District, Turlock Groundwater Basin Groundwater Management Plan, Appendix B, October 14, 1997
[20] Merced Water Supply Plan, Draft Phase 1 Report, Appendix D, CH2M-Hill, July 1993

would be required for Alternatives B and C. Approximately 21,400 participating in-lieu acres would be required for Alternatives D, E, and F

30. A detailed layout of pond locations and in-lieu acres is beyond the scope of this study. Recharge ponds would need to be located east of the area underlain by the Corcoran clay, generally east of Highway 99. Potential in-lieu acreage (lands presently using groundwater) is scattered throughout MID and TID, and all of ESWD could be served in-lieu. For this analysis, it is assumed that areas within MID or TID could be served from existing surface water conveyances. Lands to the east might also be served from the districts' canal systems, but allowance has been made for pipeline trunk conveyances and pumping plants[21].



31. Typical depth to water is about 50 feet. Drawdown in a 1500 gpm well is estimated at about 60 feet[22]. Total pumping lift is assumed as 125 feet.

[21] Assumes: Peak capacity piped conveyance to each section; Half of acres in served section take in-lieu water; Pump station with nominal 30' lift plus pipe friction losses.
[22] Transmissivity of 70,000 gpd/ft, storativity of 4E-4

Technical Memorandum: Hetch Hetchy Conveyance Hydraulics
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services

April 7, 2004

1. The conveyance system was designed to be enlarged in the future. Existing facilities were constructed at various capacities. Some of the design capacities are documented, others are not. Some facilities have conflicting design capacities documented in different sources.

2. The Hetch Hetchy system flows by gravity from Moccasin Reservoir all the way to the Peninsula. Critical high points where positive hydraulic pressures must be maintained are located at the Tesla (east) Portal of the Coast Range Tunnel and at the Crystal Springs Reservoir outfall. Overflow or surge shafts located along tunnels limit the maximum head possible in the current system.

3. For this analysis, there are three principal conveyance reaches to be considered:
    a. Foothill Tunnel (Moccasin Portal to Oakdale Portal)
    b. San Joaquin Pipelines (Oakdale Portal to Tesla Portal)
    c. Coast Range Tunnel (Tesla Portal to Irvington Portal)

4. No hydraulic test information was available for this analysis. Instead, a series of conservative assumptions was made for each of the principal conveyance reaches:

    a. For the Foothill Tunnel, loss coefficients were estimated from the tunnel invert drop of 135 feet, the head for a full Moccasin Reservoir, the stated 620 cfs design capacity, and an estimated 13-foot nominal diameter. This results in a Manning's "n" roughness value of 0.0287, which is in the midrange for such largely unlined tunnels.

    b. For the San Joaquin Pipelines, loss coefficients were calculated from the summed design capacities of 515 cfs, and a maximum allowable head decline of 415 feet (Oakdale overflow of 825 feet less Tesla crown elevation of 410). This results in a Manning's "n" roughness value of 0.0106, which is in the midrange for such mortal-lined steel pipelines.

    c. For the Coast Range Tunnel, loss coefficients were estimated from the 542 cfs (350 mgd) capacity provided by Michael Carlin, the invert drop of 80 feet, plus the maximum surcharge at the Tesla Portal overflow. This results in a Manning's "n" roughness value of 0.0150, which is in the upper range for such lined tunnels, and greater than the design value presented on SFPUC drawings. Losses of about 4 feet through the Alameda Creek Siphons are included. The Siphons have a collective rated capacity of 546 cfs.

5. The conservative assumptions listed above would limit overall flow through the system to about 480 cfs (310 mgd). The hydraulic profile of system under these assumptions is shown in Figure 1.

6. Adding a 78-inch diameter fourth barrel to the San Joaquin Pipelines would allow flow through the system to increase to about 590 cfs (380 mgd), provided that the overflow at the Tesla Portal could be extended about 30 feet, and existing facilities could be modified to withstand the additional 13 psi pressure.

7. A similar analysis using a 90-inch diameter fourth barrel suggests that 620 cfs could be conveyed through the system.

8. The assumptions outlined above introduce some uncertainties to this analysis that might be reduced through use of actual flow vs. headloss data. A 1989 analysis of the Mountain Tunnel showed that up to 750 cfs would flow through this tunnel with a design capacity of 620 cfs[23].

9. The anecdotal information on the Coast Range Tunnel is the most uncertain, since it results in friction coefficients at the extreme range of those expected for a lined tunnel. With the assumptions made, it appears the Coast Range Tunnel is the bottleneck in the Hetch Hetchy conveyance system. The Coast Range Tunnel was designed to be expanded by paralleling the existing tunnel.

10. The SFPUC has published an update of the status of high priority projects under its Capital Improvement Program relevant to system hydraulics[24].

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[23] Leedshill-Herkenhoff, Inc, 1989 Mountain Tunnel Flow Study Draft Report, prepared for Hetch Hetchy Water and Power Department, November 1989

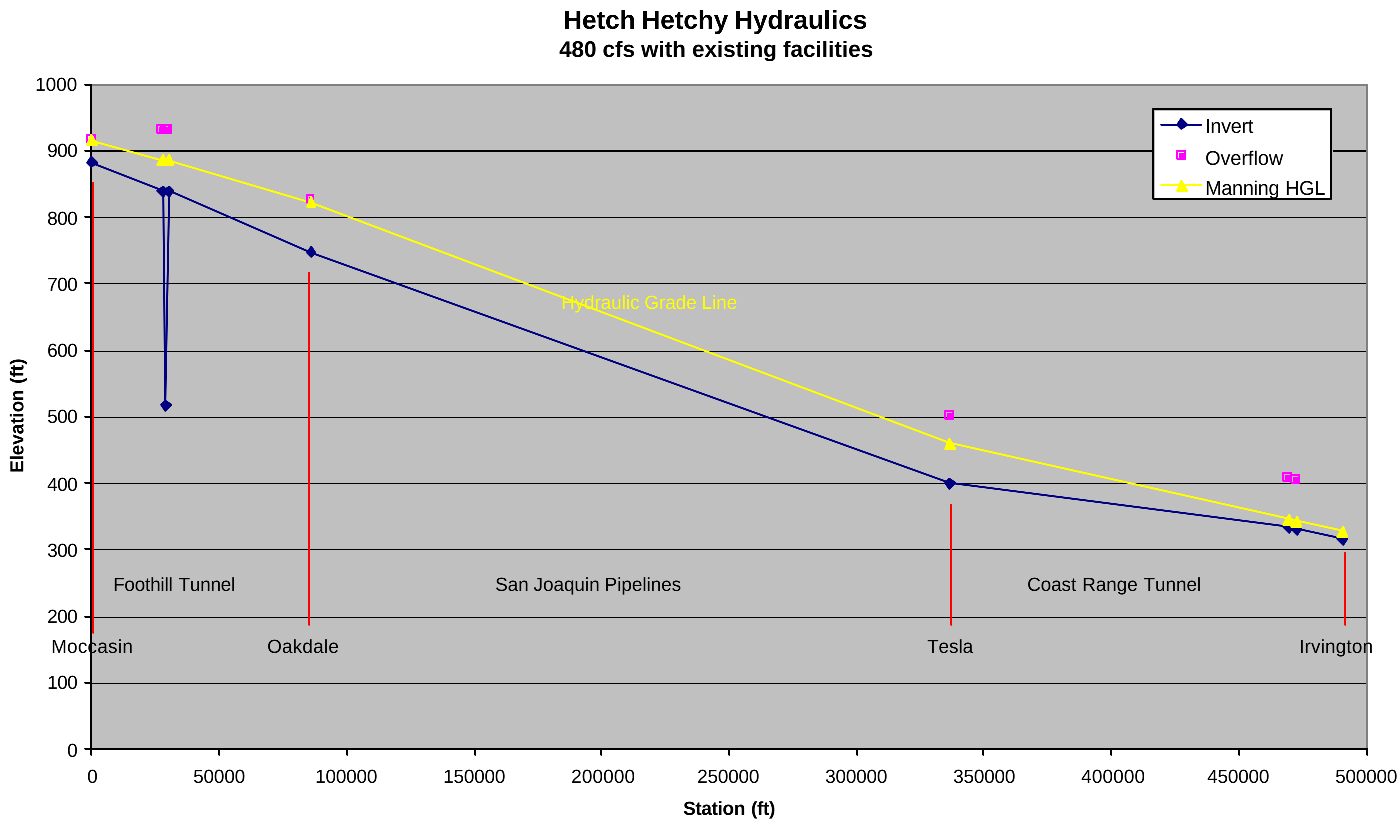
[24] Presentation by Harlan L. Kelly, Jr., SFPUC Infrastructure AGM, December 1, 2003

- Addition of a forth barrel to the San Joaquin Pipelines is included as a high priority project in the SFPUC Capital Improvement Program. The SFPUC reports that as of December 2003, the pipeline alignment and calculation of maximum allowable operating pressure for existing pipelines had been completed, and that hydraulic modeling was underway.
- Improvement or paralleling of the "Irvington Tunnel/Alameda Siphon" is included as a high priority project in the SFPUC Capital Improvement Program. Improvements have a baseline cost of $144M
- Other projects listed without elaboration include:
  - Priest Reservoir Bypass
  - O'Shaughnessy Dam Discharge Modification
  - Chloramination at SVWTP, HTWTP, and Pulgas

Hetch Hetch Conveyance Parameters\1

Feature	Invert Elevation (ft)	Length (ft)	Design Capacity (cfs)	Diameter (in)	Overflow Elevation (ft)	Manning "n"	Material
Moccasin Powerhouse	930						
Moccasin Reservoir (505 af capacity)					916		
Moccasin Portal	882\4				916		
Foothill Tunnel		27,900	620	120		0.0287	8% lined
Red Mountain Bar Siphon (Don Pedro)	839\2				930		
Red Mountain Bar Siphon	518	2,387	620	114		0.0106	mortar lined steel
Red Mountain Bar Siphon (Don Pedro)							
Foothill Tunnel		55,813	620	120		0.0287	8% lined
Oakdale Portal	747				825		
San Joaquin Pipelines							
SJPL#1		250,400	116	58		0.0106	mortar lined steel
SJPL#2		250,400	136	61		0.0106	61% mortal lined steel + concrete
SJPL#3		250,400	262\6	78		0.0106	64% mortal lined steel + concrete
SJPL#4 (proposed)		250,400	200-250\3	72-78\6		0.0106	
Total		250,400	515-765				
Tesla Portal	399				500		
Coast Tunnel		133,000	542\3	126		0.0125	lined
East Portal	333				408		
Alameda Creek Siphons							
Siphon #1		3,087	104	69		0.0106	mortar lined steel
Siphon #2		2,908	207	91		0.0106	coal tar lined steel
Siphon #3		3,018	235	96		0.0106	mortar lined steel
Total			546				
West Portal	330				405		
Coast Tunnel		18,200	542\3	126		0.0125	lined
Irvington Portal	316						
Entire Coast Range Tunnel		151,200					

\1 Data from 1985 Hetch Hetchy Data Book unless otherwise noted (Hetch Hetchy datum)
\2 Estimated from topo maps
\3 Michael Carlin, personal communication -- flow throught Coast Tunnel limited to 350 mgd (542 cfs)
\4 Invert of bypass pipeline from Moccasin Powerhouse 905'
\5 Design hydraulic gradeline 825'
\6 Estimated using same friction loss as pipelines 1 & 2


Hetch Hetchy Hydraulics
480 cfs with existing facilities
Invert
Overflow
Manning HGL
Hydraulic Grade Line
Foothill Tunnel
San Joaquin Pipelines
Coast Range Tunnel
Moccasin
Oakdale
Tesla
Irvington
Elevation (ft)
Station (ft)
0
100
200
300
400
500
600
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400000
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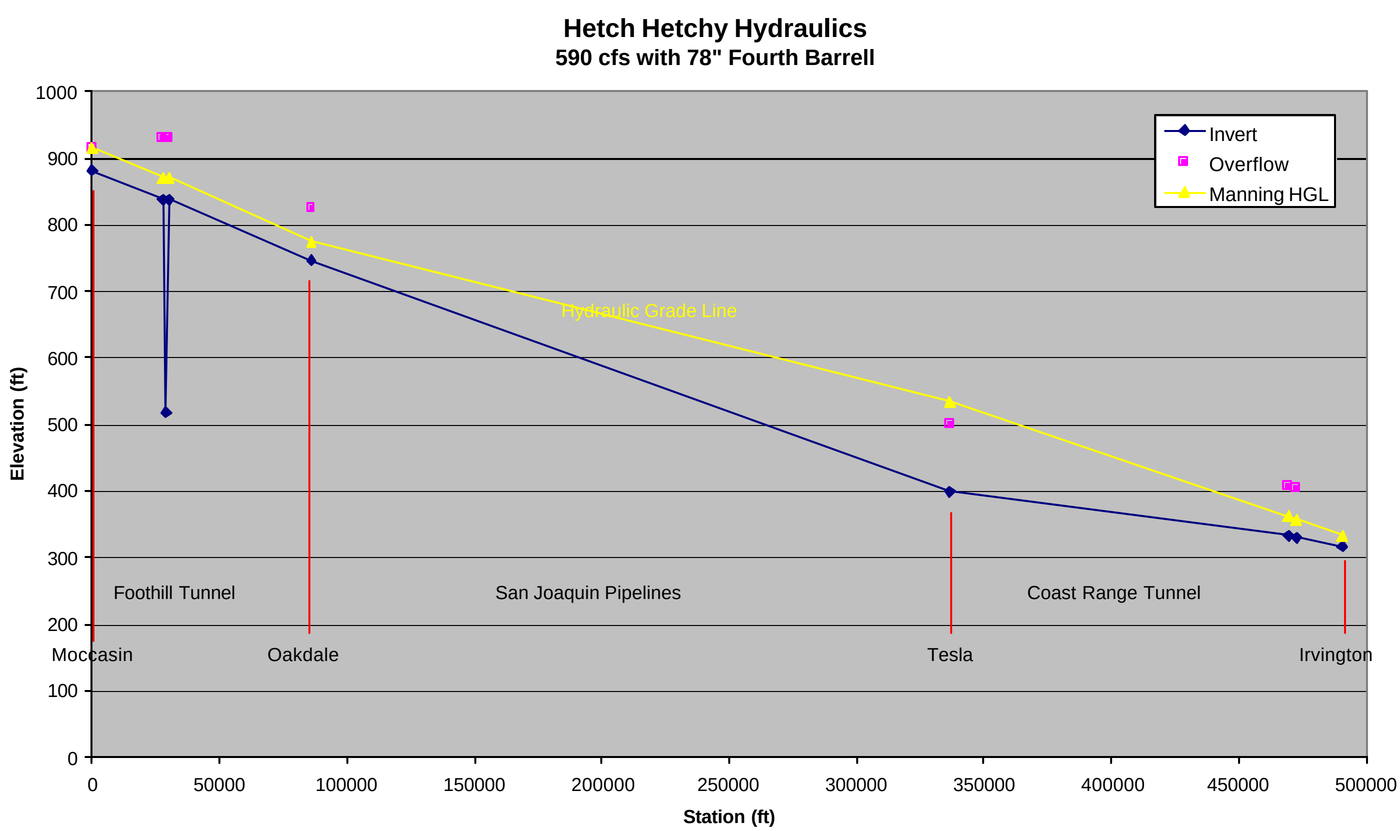
Hetch Hetchy Hydraulics
590 cfs with 78" Fourth Barrell
Invert
Overflow
Manning HGL
Hydraulic Grade Line
Foothill Tunnel
San Joaquin Pipelines
Coast Range Tunnel
Moccasin
Oakdale
Tesla
Irvington
Elevation (ft)
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CalSim Delta Alternatives Modeling
Hetch Hetchy Reservoir Replacement Alternatives

Schlumberger Water Services
June 8, 2004

Introduction

This document describes the basic approach and modeling results for CALSIM model runs that were performed by Schlumberger Water Services to model the delivery of Tuolumne River water to the service area of the San Francisco Public Utilities Commission (SFPUC) via the California Aqueduct. The study "OCAP 2001 Today EWA" (http://www.usbr.gov/mp/cvo/ocap.html) was used as a basis for these model studies, with input data developed by the Tuolumne River Equivalent Water Supply Simulation Model (TREWSSIM) developed by Environmental Defense (ED). The following alternatives were analyzed:

- Baseline alternatives: the Baseline alternatives are the same as the OCAP 2001 WITH EWA study, except that the inflow time series into New Don Pedro was replaced with an inflow time series developed by the TREWSSIM model. The revised inflows are volumetrically similar to those contained in the OCAP study. Two different Baseline alternatives were analyzed with SFPUC delivery objectives of 260 and 303 MGD.
- Delta alternatives: in these alternatives, the Baseline alternatives were modified to reflect operations with Hetch Hetchy Reservoir removed. CALSIM was used to model water that could not be delivered directly to the Hetch Hetchy Aqueduct and had to be cycled through the Delta to be delivered to the SFPUC. The basic assumptions for each of the four Delta alternatives are shown in Table 1.

Table 1. Basic Assumptions for the Delta Alternatives

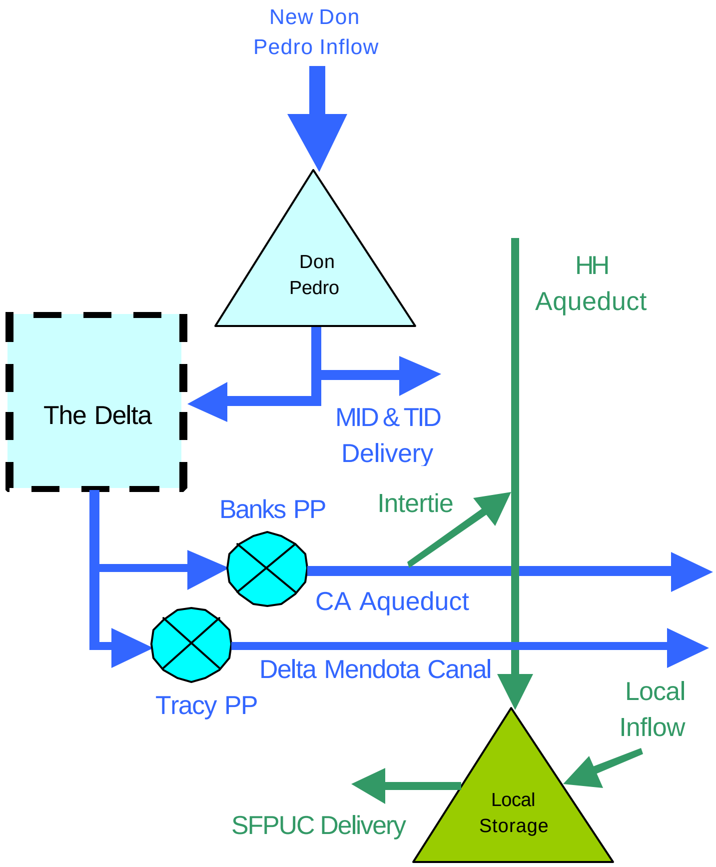
Alternative	Calaveras Storage	San Joaquin Pipelines Capacity	SFPUC Delivery Objective
Delta 1	97 TAF	300 MGD	260 MGD
Delta 2	260 TAF	350 MGD	303 MGD
Delta 3	420 TAF	350 MGD	303 MGD
Delta 4	97 TAF	350 MGD	303 MGD

Approach

The basic operating parameters for the Delta alternatives are depicted in the Figure 1. Items in blue are present in the Baseline alternatives, while items in green were added for the Delta alternatives. The following facilities were added to the CALSIM Baseline alternatives for these alternatives:

- Hetch Hetchy Aqueduct
- Intertie between the California and Hetch Hetchy Aqueducts
- A local storage node for the SFPUC's Bay Area reservoirs
- A delivery link to the SFPUC

Figure 1. Operating Paramaters for the Delta Alternatives



The operation of the Tuolumne River system above New Don Pedro Reservoir was pre-operated in the TREWSSIM model by ED, producing time series of inflows into New Don Pedro Reservoir and run-of-river diversions into the Hetch Hetchy Aqueduct. The CALSIM model was used to estimate changes in Delta flows and in pumping at the Banks and Tracy pumping plants given increased inflows from the Tuolumne River system and an additional South-of-Delta demand for the SFPUC. Deliveries to SFPUC were made via an intertie between the California and Hetch Hetchy Aqueducts, where they were combinded with the run-of river diversions and delivered to the local SFPUC storage node. This storage node was operated to meet SFPUC's delivery objective.

Tuolumne River Operations
The following assumptions for representation of the Tuolumne River were used to modify the Baseline alternatives for the Delta alternatives:

- Inflows into New Don Pedro Reservoir were changed to those produced by the TREWSSIM model
- Flood control space requirements at Don Pedro were increased by 30 TAF from October through March to replace flood control space previously held in the Hetch Hetchy Reservoir
- Instream flow requirements on the Tuolumne River were set at the same monthly values as were produced by the 260 MGD Baseline alternative
- Groundwater pumping for the Turlock and Modesto Irrigation Districts were set at the same monthly values as were produced by the 260 MGD Baseline alternative

Delta Operations
Rather than attempt to model pumping in Banks and Tracy Pumping Plants for the SFPUC directly, it was assumed that the State Water Project (SWP) and Central Valley Project (CVP) used the same operating policies as in the Baseline alternatives, except that additional water was available from the Tuolumne River and a portion of the water pumped at Banks Pumping Plant was used to deliver water to the SFPUC via the California Aqueduct. The SFPUC delivery link off of the California Aqueduct was given a high priority (high weight) in order to ensure that it received first priority in South of Delta deliveries.

SFPUC Local Operations
ED provided a time series of local inflows into the SFPUC's Bay Area reservoirs. These inflows were combined with the run-of-river and intertie flows from the Hetch Hetchy Aqueduct and delivered to the SFPUC local storage node. The aggregate local storage node had a capacity equal to the combined capacities of the Calaveras, San Antonio, San Andreas, Crystal Springs, and Pilarcitos Reservoirs and was used to regulate both the local inflow and the imported supplies to meet SFPUC's demand. The flood storage space of the Peninsula Reservoirs was represented from July to March. Intermediate storage levels were set so that a portion of the active storage space had a higher priority for filling than did deliveries to the SWP and CVP contractors while the rest of the active storage space was only filled after all SWP and CVP deliveries were made.

Storage in this node was operated to try to meet SFPUC's delivery objective for each alternative. The delivery objective was set at the actual time series of deliveries, including shortages, at each level of demand from the TREWSSIM model. This objective was given the highest priority in the system to ensure that it was always met in every month. This operation thus describes operations that might be possible if the SFPUC were to be delivered water from the California Aqueduct.

Model Results

The model results indicate that delivering water to the SFPUC through the Delta would cause changes in operations of the Tuolumne River, Delta, and the SFPUC local system. In addition, the maintenance of SFPUC delivery reliability at Baseline alternative levels would require changes in SWP and CVP operations and possible reductions in project deliveries. Model results for each of these areas are described below. In the presentation of the results, Baseline alternative values are shown where available. Delta 1 alternative results are shown as differences from the 260 MGD Baseline alternative, while the results of the Delta 2, 3, and 4 alternatives are shown as differences from the 303 MGD Baseline alternative.

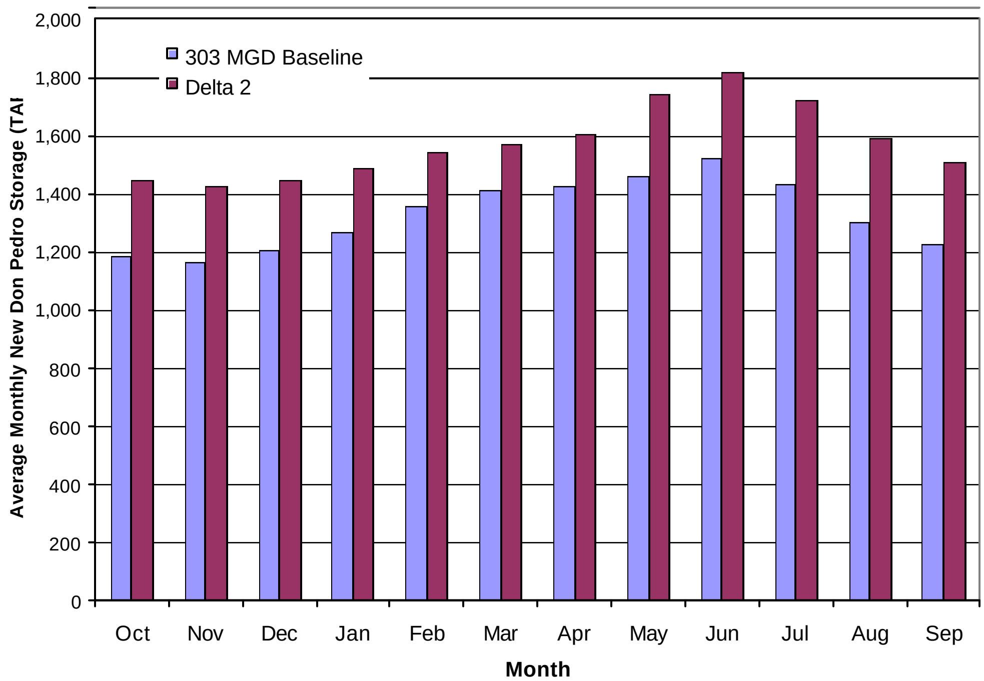
Tuolumne River Operations

Table 2 shows data describing Tuolumne River operations for each alternative. The 260 MGD Baseline alternative had an average annual New Don Pedro inflow of about 1,520 TAF per year while the 303 MGD Baseline alternative had an average annual inflow of about 1,464 TAF per year. This difference occurred because higher SFPUC demands resulted in greater Hetch Hetchy Aqueduct diversions in the TREWSSIM model. The Delta 1 alternative had an average annual inflow about 79 TAF higher than the 260 MGD Baseline alternative. The Delta 2, 3, and 4 alternatives had about 111-114 TAF more inflow per year than the 303 MGD Baseline alternative.

Table 2. Tuolumne River System Results

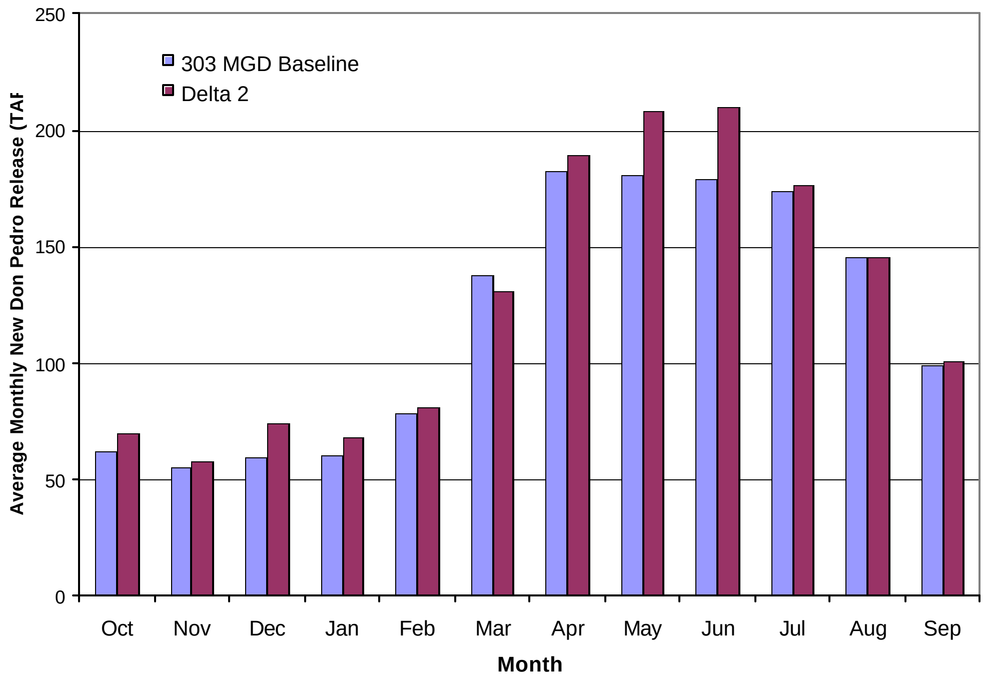
Alternative	**New Don Pedro Operations**			**Modesto & Turlock ID Deliveries (TAF/year)**
	Annual Inflow (TAF/year)	Annual Release (TAF/year)	Avg Storage (TAF)	
260 MGD Baseline	1,520	1,463	1,415	1,108
Delta 1	+79	+69	+178	+0
303 MGD Baseline	1,464	1,413	1,330	1,108
Delta 2	+114	+99	+245	+0
Delta 3	+111	+96	+245	+0
Delta 4	+113	+98	+245	+0

Figure 2. Average Monthly New Don Pedro Storage



With these additional inflows, New Don Pedro reservoir was operated at higher storage levels than the Baseline alternatives in all of the Delta alternatives. As an example, Figure 2 shows the average annual storage in New Don Pedro Reservoir in each month in the 303 MGD Baseline and Delta 2 alternatives. The Delta 2 alternative had higher average storage levels in every month compared to the Baseline alternative. In addition, for all of the Delta alternatives average annual New Don Pedro releases increased relative to the Baseline alternatives by almost as much as the increase in New Don Pedro inflows. Most of the increases in releases for each of the Delta Alternatives occurred in May and June. As an example, Figure 3 shows average annual New Don Pedro releases for the 303 MGD Baseline and Delta 2 alternatives. Similar patterns held for all of the Delta alternatives.

Figure 3. Average Monthly New Don Pedro Releases



The high storage levels and New Don Pedro releases shown for the Delta 2 alternative in May and June occurred because the New Don Pedro inflow without Hetch Hetchy showed increases in these months during most years. These increased inflows meant that the reservoir storage hit the maximum storage level more often and consequently there were additional flood releases during these months. As will be shown below, all of the Delta alternatives showed increases in Delta outflows in addition to additional Banks and Tracy pumping amounts. It is possible that the timing of the New Don Pedro releases could influence the amount of the additional New Don Pedro release that the model was able pump at Banks and Tracy. Preliminary efforts were made to shift the New Don Pedro operating rules to release more water in July through September and less in May and June, but these efforts did not result in increased Delta pumping quantities. The re-operation of New Don Pedro reservoir to better utilize the increased Tuolumne River inflow is a possible improvement that could be explored in subsequent studies.

There were small differences between average annual releases and inflows, which occurred because of increased evaporation due to operating the reservoir at slightly higher storage levels in the summer months and because of differences in end-of-simulation storage levels.

Finally, deliveries to the Modesto and Turlock Irrigation District were identical in all alternatives. Therefore, all of the additional New Don Pedro releases flowed into the Delta.

Delta Operations

Table 3 shows average annual Banks and Tracy pumping and average annual Delta outflow for each alternative. All of the Delta alternatives showed increases in Banks pumping and Delta outflows over the Baseline alternatives, with relatively small changes in Tracy pumping amounts. Banks pumping increased in an effort to meet the additional South of Delta demand off of the California Aqueduct for the SFPUC. However, the model was unable to utilize all of the increase in New Don Pedro releases because in many cases the increased releases occurred in months when all of the South of Delta demand was already met or when no additional pumping was possible due to Delta constraints or Banks and Tracy capacity limitations. Thus, in all of the Delta alternatives a portion of the increased New Don Pedro release relative to the Baseline alternatives was lost to the system as increased Delta outflow.

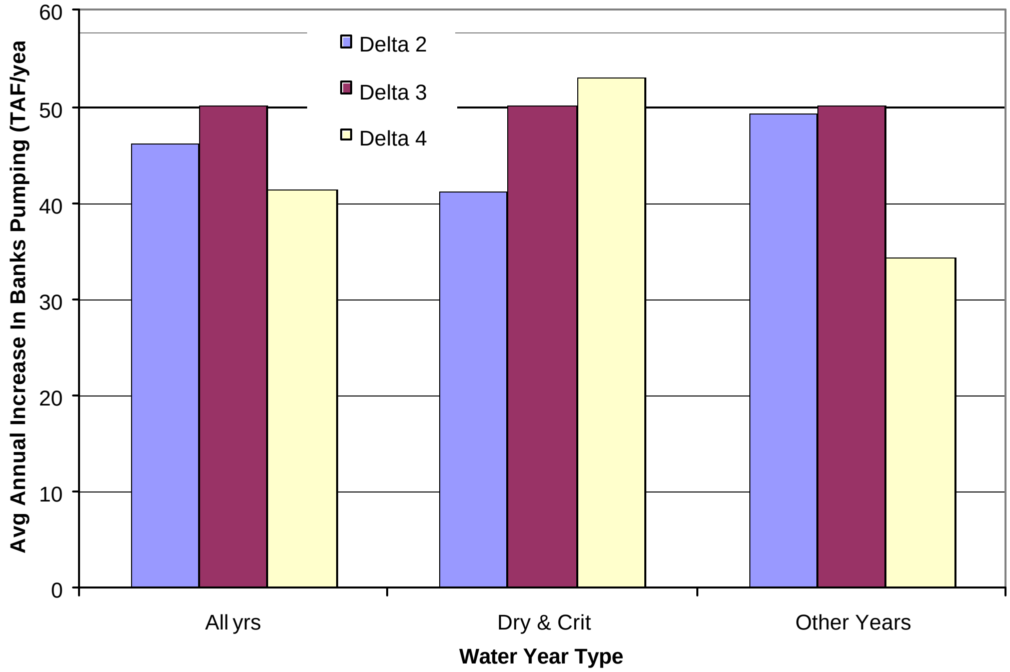
Table 3. Delta Results

	Banks PP Pumping (TAF/year)	Tracy PP Pumping (TAF/year)	Delta Outflow (TAF/year)
260 MGD Baseline	3,262	2,321	14,278
Delta 1	+41	+0	+31
303 MGD Baseline	3,261	2,321	14,232
Delta 2	+46	+2	+50
Delta 3	+50	+0	+45
Delta 4	+42	-2	+59

A comparison of Banks pumping amounts in the Delta 2, 3, and 4 alternatives reveals that the average annual amount of pumping increased as the size of Calaveras Reservoir was increased. In Delta 4, in which Calaveras storage is set at the current level of 97 TAF, Banks pumped an average of about 42 TAF per year more than in the Baseline alternative. When Calaveras Storage was increased to 260 TAF in the Delta 2 alternative, average annual Banks pumping increased by about 4 TAF, and when Calaveras storage was increased an additional 160 TAF to 420 TAF, average annual Banks pumping increased by an additional 4 TAF.

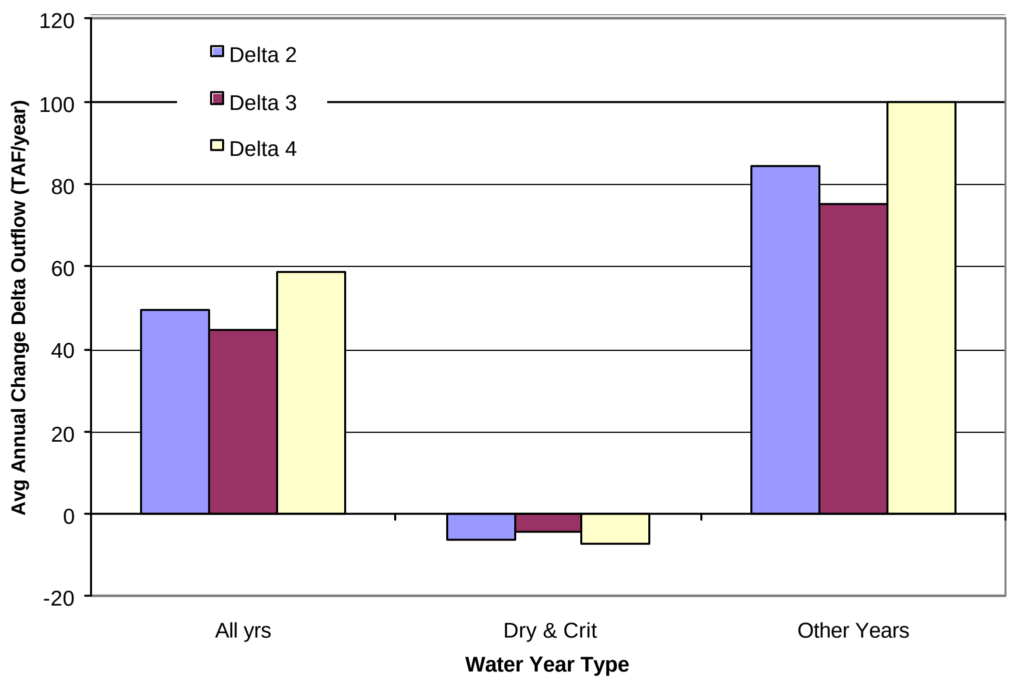
Even with this overall increase in Banks pumping, the amount of Banks pumping during Dry and Critical years was less in the Delta 2 and 3 alternatives than in the Delta 4 alternative. Figure 4 shows the change average annual Banks pumping relative to the Baseline alternative in each of these alternatives in dry and critical years and other years. Banks pumping in dry and critical years was about 10 TAF per year less in the Delta 2 alternative than it was in the Delta 4 alternative. This had a beneficial benefit for flows in the Delta during dry and critical years. Figure 5 shows the change in Delta outflow relative to the Baseline alternative for the Delta 2, 3, and 4 alternatives. Delta outflow during dry and critical years was higher in the Delta 2 and 3 alternatives than it was in the Delta 4 alternative.

Figure 4. Average Annual Change in Banks Pumping Relative to the Baseline



Alternative

Figure 5. Average Annual Change in Delta Outflow Relative to the Baseline



Alternative

SFPUC Local Operations

Table 4 shows data describing local SFPUC operations. Because the local SFPUC system was not modeled in the Baseline alternatives, Table 4 shows absolute values for the local SFPUC operating parameters in each alternative. The Delta 1 alternative delivered the same amount of water to the SFPUC as was delivered by the TREWSSIM model in the Baseline alternative with a delivery objective of 260 MGD. The Delta 2, 3, and 4 alternatives delivered the same amount of water to the SFPUC as was delivered by the TREWSSIM model in the Baseline alternative with a delivery objective of 303 MGD. An annual time series of SFPUC deliveries can be seen for each alternative in Figure 6. In all alternatives the SFPUC experienced shortages during the historical dry periods.

Figure 6. SFPUC Deliveries

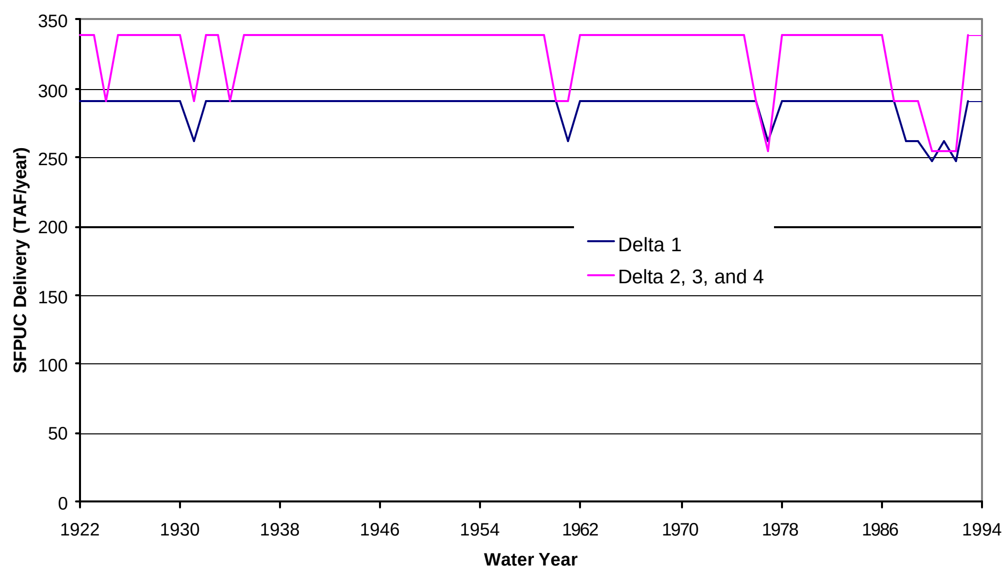


Table 4. Local SFPUC Results

	Delta 1	Delta 2	Delta 3	Delta 4
SFPUC Delivery (TAF/year)	288	329	329	329
Local Inflow (TAF/year)	47	47	47	47
Hetch Hetchy Run-of-river diversions (TAF/year)	184	205	207	205
CA Aqueduct Diversions to SFPUC (TAF/year)	75	94	95	94
Local SFPUC Reservoir Evaporation (TAF/year)	13	16	19	13
Local SFPUC Reservoir Spills (TAF/year)	7	1	1	6
Local SFPUC Reservoir Average Storage (TAF)	154	240	322	154

To make these deliveries, all of the Delta alternatives used a combination of local inflow into the local SFPUC storage node, run-of-river diversions to the Hetch Hetchy Aqueduct, and diversions from the California Aqueduct via the modeled Hetch Hetchy Aqueduct intertie. About 75 TAF per year was delivered to the SFPUC from the California Aqueduct in the Delta 1 alternative, while about 94-95 TAF per year was delivered to the SFPUC from the California Aqueduct in the Delta 2, 3, and 4 alternatives.

Figure 7 shows the average annual California Aqueduct diversion to the SFPUC under the Delta 2, 3, and 4 alternatives in all years and in dry and critical years. The SFPUC received more deliveries in dry and critical years than in other years in all three alternatives. However, there was a slight difference in the timing of deliveries between these three alternatives as in the Delta 2 and 3 alternatives the SFPUC received 2 to 4 TAF less per year than in the Delta 4 alternative. This occurred because the increased SFPUC storage capacity in the Delta 2 and 3 alternatives allowed for more water to be taken from the California Aqueduct to fill the local storage node in months of excess water availability when all other South of Delta demands have been met. This in turn allowed for fewer diversions during drier months when there may be more South of Delta demand than supply. This contributed to the increase in deliveries to the SWP and CVP (as discussed below).

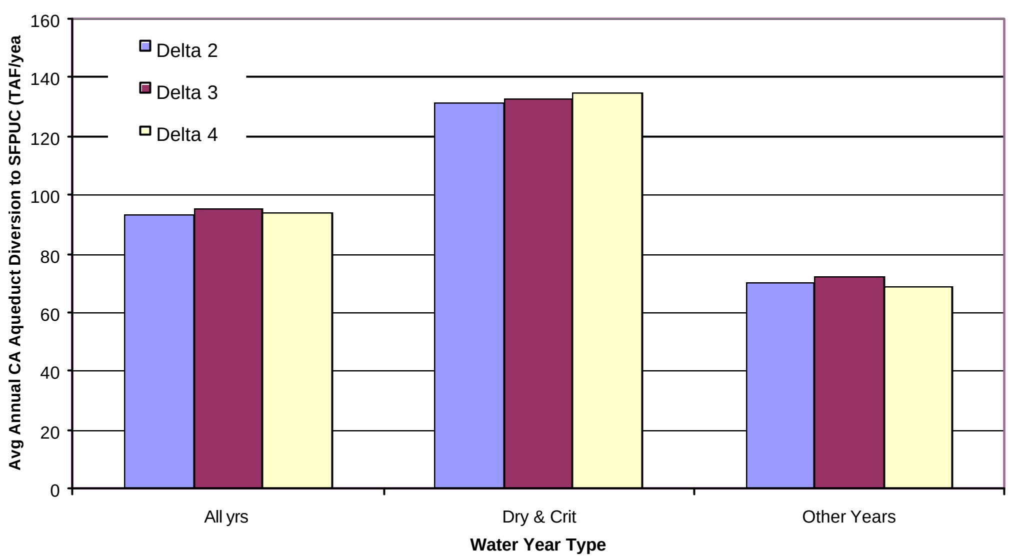
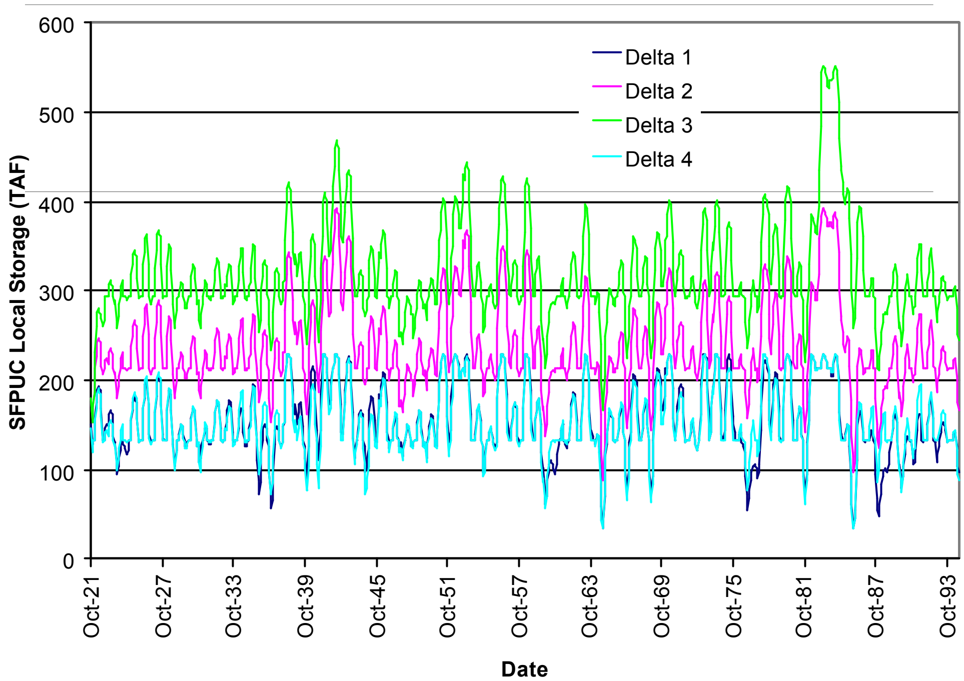


Figure 7. Average Annual California Aqueduct Diversions to SFPUC

The local SFPUC storage node operated at higher storage levels in the Delta 2 and 3 alternatives as compared to the Delta 1 and 4 alternatives, resulting in higher evaporation amounts. Figure 8 shows the monthly storage level of the local SFPUC storage node in each alternative. In each alternative, the operation of the storage node reflected an annual cycle of increasing storage in the winter and spring and reducing storage in the summer and fall. In the Delta 3 alternative the reservoir was consistently operated at a higher storage level than in the other alternatives, with an average storage of about 322 TAF compared to average storages of about 240 TAF in the Delta 2 alternative and about 154 TAF in the Delta 1 and 4 alternatives.

All of the Delta alternatives experienced losses from the local SFPUC storage node due to evaporation and "spills". These spills occurred because of a limitation to this modeling approach where the Tuolumne River portion of SFPUC's system was pre-operated separately in the TREWSSIM model. The spills occurred in months when the sum of the local inflow and Hetch Hetchy run-of-river diversion was greater than the sum of the SFPUC delivery objective and the amount of storage space remaining in the SFPUC storage node. This occurred more often in the Delta 1 and 4 alternatives than in the Delta 2 and 3 alternatives because the available storage space was smaller. In reality, these "spills" represent the amount of reductions that the SFPUC would make in run-of-river diversions rather than actual spills from the local reservoirs. However, the actual amount of spill was relatively small at only about 7 TAF per year in the Delta 1 and 4 alternatives and about 1 TAF per year in the Delta 2 and 3 alternatives.

Figure 8. Monthly Storage in the Local SFPUC Storage Node



The increased amount of spills in the Delta 1 and 4 alternatives were balanced by the increased evaporation in the Delta 2 and 3 alternatives, which resulted in approximately the same amount of losses in each alternative and therefore in approximately the amount of diversions being required from the California Aqueduct in the Delta 2, 3, and 4 alternatives.

SWP and CVP Delivery Reliability

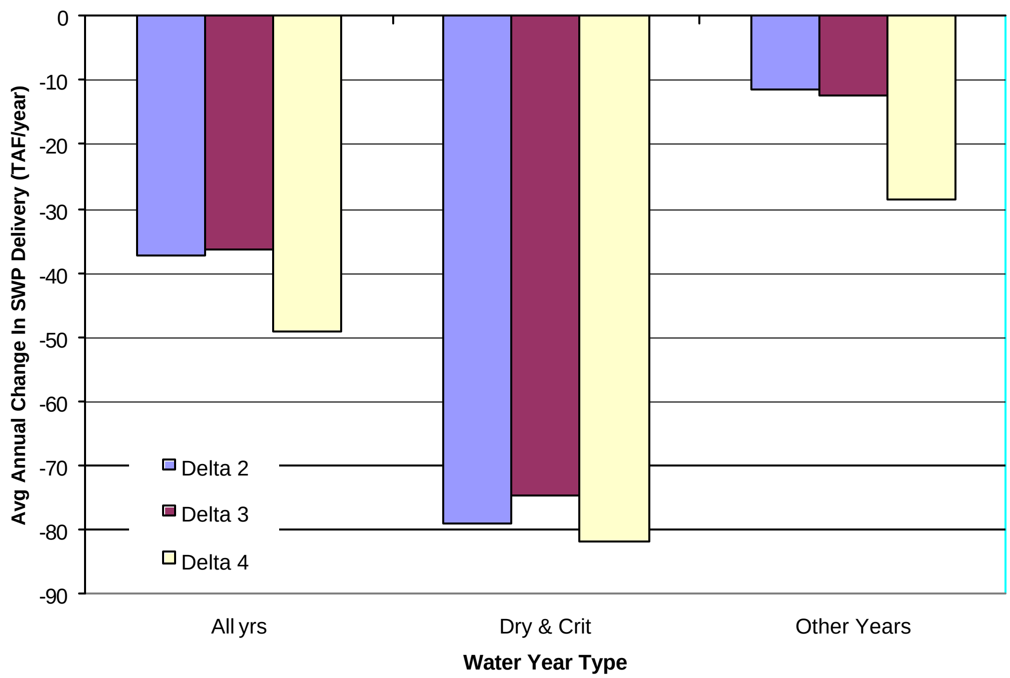
Table 5 shows average annual deliveries to SWP and CVP contractors under each alternative. The SWP and CVP received fewer deliveries than occurred in the Baseline alternatives in each Delta alternative. These shortages occurred because inefficiencies in Delta operations did not allow all of the increased water released from New Don Pedro in the Delta alternatives to be pumped at Banks and Tracy pumping plants. In reality, the SWP and CVP would not experience any additional shortages due to the removal of Hetch Hetchy Reservoir because they have priority in Banks and Tracy pumping. However, the quantities of SWP and CVP shortage shown for each alternative provide an estimate of how much water might need to be acquired South of Delta in order to keep SFPUC delivery reliability at the same level as in the Baseline alternatives.

Table 5. Average Annual SWP and CVP Deliveries

	SWP Delivery (TAF/year)	CVP Delivery (TAF/year)	Total Project Delivery (TAF/year)
260 MGD Baseline	3,047	4,765	7,812
Delta 1	-26	-9	-35
303 MGD Baseline	3,048	4,763	7,811
Delta 2	-37	-9	-46
Delta 3	-36	-9	-45
Delta 4	-49	-7	-56

A comparison of the SWP deliveries in the Delta 2, 3, and 4 alternatives reveals that as Calaveras storage capacity was increased above the current capacity of 97 TAF per year the average annual delivery to the SWP increased as well. Figure 9 shows the average annual change in SWP deliveries relative to the Baseline alternative for the Delta 2, 3, and 4 alternatives. The change in SWP deliveries occurred because there was increased pumping at Banks in the Delta 2 and 3 alternatives as compared to the Delta 4 alternative as discussed above. Consistent with what was shown above for Banks pumping, the increase in SWP deliveries occurred primarily in years other than dry and critical years. However, there was a small increase in SWP deliveries in dry and critical years as storage was increased in Calaveras Reservoir as well.

Figure 9. Average Annual Change in SWP Deliveries



Limitations

The CALSIM model is the best tool currently available for modeling operations of the SWP, CVP, and the Delta in an integrated manner. However, in its current state of development it has many limitations, many of which were identified in the *Strategic Review for CALSIM and its Use for Water Planning* (CBDA 2003). Some of the limitations identified in this report include the need for updating the current demand and hydrology assumptions contained in the model, better representation of groundwater resources, and including various local systems not currently represented in the model. Operating the model in comparative mode, in which the results of different model runs are compared to one another, can mitigate the effects of many of these limitations.

There are additional limitations specific to the modeling approach employed in this model study. These limitations reflect that this modeling study was intended to explore the possible effects of delivering Tuolumne River water to the SFPUC through the Delta, not to develop specific operating rules for such an operation. The limiations include the following:

- The local SFPUC system was modeled in a simplified manner with all Bay Area reservoirs aggregated into a single storage node. This allowed for more system flexibility than would be possible in reality. In addition, the logic used for deliveries to the SFPUC were simplified by assuming a pre-processed time series of monthly demands, with shortages, developed by the TREWSSIM model and giving deliveries to satisfy these demands a very high weight in order to guarantee that they would always be met in every time step.

- Operations upstream of New Don Pedro Reservoir on the Tuolumne River were modeled separately in the TREWSSIM model. The use of two separate models did not allow for the coordination of the SFPUC's Tuolumne River and Bay Area systems
- No effort was made to set proper priorities for the SFPUC's use of Banks Pumping Plant. The SFPUC's use of Banks Pumping Plant was modeled simply by assuming that the SFPUC would receive first priority in South of Delta deliveries. This resulted in reductions in deliveries to the SWP and CVP which would not occur in reality but were used as an indication of how much water would have to be acquired South of Delta in order to not have reductions in the SFPUC's delivery reliability.
- New Don Pedro reservoir operating rules were not modified from those contained in the Baseline alternatives. This results in higher storage levels and additional spills in May and June. Preliminary efforts were made to shift the New Don Pedro operating rules to release more water in July through September and less in May and June, but these efforts did not result in increased Delta pumping quantities. However, it may be possible to adjust New Don Pedro reservoir operations to allow for greater pumping in the Delta.

Conclusions

The results of this modeling study provide insight into possible operating alternatives for routing SFPUC water through the Delta to replace water supply that could not be delivered through the Hetch Hetchy Aqueduct if Hetch Hetchy Reservoir were removed. The results indicate the following:

- In order for the SFPUC to have the same delivery reliability as in the Baseline alternatives, about 75 TAF per year may need to be diverted from the California Aqueduct with a SFPUC demand of 260 MGD and about 94-95 TAF per year may need to be diverted with a SFPUC demand of 303 MGD.
- If additional releases are made from New Don Pedro Reservoir, it should be possible to increase pumping quantities at Banks Pumping Plant to meet additional demands South of Delta off of the California Aqueduct. All four Delta alternatives had an additional 40 to 50 TAF in average annual Banks pumping over the Baseline alternatives.
- Restrictions on Delta pumping will cause a portion of any additional water released from New Don Pedro to flow out the Delta. Each Delta alternative had an additional 30 to 60 TAF in average annual Delta outflow over the Baseline alternatives.
- Given the restrictions on Delta pumping, it may be necessary for the SFPUC to acquire water South of Delta to make sufficient deliveries off of the California Aqueduct to ensure the same delivery reliability as in the Baseline alternatives. In

each Delta alternative, it was necessary to reduce average annual deliveries to other South of Delta users by 36 to 56 TAF per year.

- The enlargement of Calaveras Reservoir may allow for more water to be pumped at Banks and therefore require fewer acquisitions of other South of Delta supplies. At 303 MGD of demand, an average of 56 TAF per year was required in the Delta 4 alternative at the current storage capacity of 97 TAF, but an average of only 45 TAF per year was required in the Delta 3 alternative when the storage capacity was increased to 420 TAF.

Appendix: CALSIM Modifications

This appendix describes changes that were made to the CALSIM input files to model the Delta alternatives. The study "OCAP 2001 Today EWA" (http://www.usbr.gov/mp/cvo/ocap.html) was used as a basis for these model runs. The changes relative to the OCAP study that were made for each model run are shown in the tables below.

Tuolumne River operations above New Don Pedro Reservoir were performed using the TREWSSIM model developed by Environmental Defense. Output data from the TREWSSIM model was used as input data into the CALSIM model as noted in the table.

<u>Tuolumne River Representation</u>
Table A-1 shows the modifications that were made to the representation of the Tuolumne River relative to the OCAP study.

Table A-1. CALSIM Modifications to Tuolumne River Representation

	Baseline Alternatives	Delta 1	Delta 2	Delta 3	Delta 4
New Don Pedro inflow (I81)	Inflow time series modified to that contained in the TREWSSIM model				
New Don Pedro storage levels (S81_3 and S81_4) and weights	No change	The values of storage levels 3 and 4 were reduced by 30 TAF from Oct-Mar to reflect the shift of Hetch Hetchy's flood storage pool to New Don Pedro Reservoir.			
MID & TID Groundwater pumping (GP540 and GP 541)	No change	GP540 and GP541 were removed from the connectivity tables and replaced with new inflow arcs I540 and I541. The values of I540 and I541 were set as time series equal to the flows on GP540 and GP541 in the 260 MGD Baseline alternative			
Tuolumne River minimum flows (C540_mif,C542_mif and C544_mif)	No change	Minimum instream flows on arcs C540, C542, and C544 were frozen at the 260 MGD Baseline alternative levels. This was accomplished by changing the MIF type for these arcs from 'WRESL' to 'TIMESERIES' in the channel tables. The input time series for these minimum instream flows were set equal to the output minimum instream flows from the 260 MGD Baseline alternative. In addition, all references to C540_mif, C542_mif and C544_mif were removed from the files bounds_cycle2.wresl, bounds_cycle3.wresl, bounds_cycle4.wresl, and bounds_cycle5.wresl.			

<u>SFPUC Local Representation</u>
In order to model the delivery of Tuolumne River water to the SFPUC service area a new network was added to the CALSIM model to depict SFPUC's local system. Figure A-1

depicts the new network that was added to represent the SFPUC local system in the Delta alternatives. The local system representation included an intertie to deliver water from the California Aqueduct to the Hetch Hetchy Aqueduct and an aggregate local storage reservoir that included the capacities of the Peninsula, San Antonio, and Calaveras Reservoirs.

Figure A-1. CALSIM Representation of Local SFPUC System

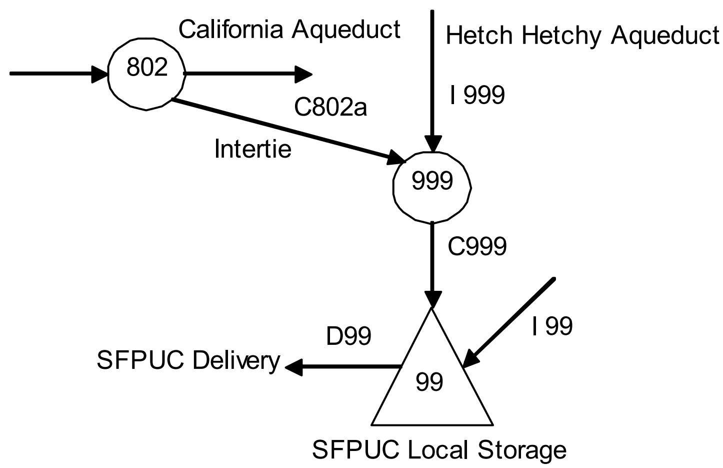


Table A-2 shows the modifications that were made to the CALSIM input files to model the operation of SFPUC's local system.

Table A-2. CALSIM Modifications for Local SFPUC Representation

Hetch Hetchy Aqueduct Inflow (I999)	New inflow arc was added to depict Hetch Hetchy run-of-river dicersions into the Hetch Hetchy Aqueduct. Inflow time series was taken from the ED spreadsheet model
CA Aqueduct to Hetch Hetchy Aqueduct intertie (C802a)	New arc was added to the channel tables and to the connectivity tables with flows starting at node 802 on the California Aqueduct
Hetch Hetchy Aqueduct flow (C999)	New arc was added to the channel tables and to the connectivity tables; maximum capacity set to 465 cfs for the Delta 1 alternative and 542 cfs for the other scenarios
SFPUC local inflow (I99)	New inflow arc was added to depict local inflow into SFPUC reservoirs. Inflow time series was taken from the TREWSSIM model
SFPUC Delivery arc (D99)	SFPUC demand was set equal to a time series of the actual monthly deliveries (including shortages) from the TREWSSIM model at each demand level; Weight = 500,000 to ensure 100% delivery in all months
SFPUC Local Storage (D99)	
Storage Levels	Level 1 = 35 TAF Level 2 = 229 TAF for Delta 1 & 4, 213 TAF for Delta 2, 293 TAF for Delta 4 Level 3 = 229 TAF for Delta 1 & 4, 273 TAF for Delta 2, 379 TAF for Delta 4 Level 4 varied by month to reflect flood storage pool in Peninsula reservoirs Level 5 = 229 TAF for Delta 1 & 4, 392 TAF for Delta 2, 552 TAF for Delta 4
Weights	Storage Level 1 = 100,000 Storage Level 2 = 1,000 Storage Level 3 = 15 Storage Level 4 = 10 Storage Level 5 = -50,000 Flood Release = -10,000
Evaporation	Set to try to mimic monthly storage versus evaporation equations provided by Environmental Defense. To accomplish this, dummy values were entered in the Res_info table for surface area at each level of storage. Using these dummy values, an evaporation time series was developed to try to replicate the equations provided by Environmental Defense.

APPENDIX B

Water quality evaluation for Hetch Hetchy Reservoir alternatives

Prepared by EOA, Inc. for Environmental Defense

WATER QUALITY EVALUATION

FOR HETCH HETCHY RESERVOIR ALTERNATIVES

Prepared for

Environmental Defense

Prepared by

EOA, Inc.

1410 Jackson St.
Oakland, CA

TECHNICAL MEMORANDUM

WATER QUALITY EVALUATION

FOR HETCH HETCHY RESERVOIR ALTERNATIVES

Prepared for

Environmental Defense

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TECHNICAL MEMORANDUM

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Executive Summary

ES.1 Introduction

Environmental Defense is evaluating the feasibility of restoring the Hetch Hetchy Valley and is therefore exploring alternatives for the water supply, water quality and power benefits currently made possible by the Hetch Hetchy Reservoir. Restoring the Hetch Hetchy Valley would require coordination of many technical, operational, and political considerations. To understand the potential water quality issues associated with restoring Hetch Hetchy Valley, Environmental Defense retained EOA, Inc. to carry out a planning level evaluation of existing and potential future water quality, both with and without the Hetch Hetchy Reservoir. This technical memorandum summarizes the results of that planning level water quality evaluation.

This planning level water quality evaluation is based on available data and information, and includes the following:

1. A summary of the existing San Francisco Public Utilities Commission (SFPUC) Hetch Hetchy water system and an overview of current operations;
2. Data summaries for raw waters that are representative of SFPUC source waters;
3. Data summaries for treated waters that are representative of SFPUC delivered water;
4. A summary of current finished (treated) water quality;
5. Estimated raw water quality for future (2030) demand assuming that the Hetch Hetchy Reservoir continues to be a part of the water supply system;
6. Estimated raw water quality for future (2030) demand for three alternative operational strategies to the Hetch Hetchy Reservoir; and
7. A description of the types of water treatment that would be needed for the alternative operational strategies so that future finished water would be of similar quality to the current finished water.

ES.2 Overview of SFPUC Hetch Hetchy Water Supply System

The SFPUC water supply system is comprised of reservoirs in the Sierra Nevada and the San Francisco Bay Area (Bay Area), hydroelectric generation facilities, conveyance pipelines and water treatment facilities (refer to Figure 1.2). This water system produces an average of approximately 300 million gallons of water per day and approximately 1.7 billion KW hrs of hydropower each year (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000; U.S. Bureau of Reclamation 1987). The system supplies water to the city and county of San Francisco, as well as parts of San Mateo, Santa Clara, and Alameda Counties.

There are three primary sources of water in the SFPUC water system (CH2M HILL 1995; San Francisco Public Utilities Commission and Bay Area Water Users Association 2000):

- ◇ Tuolumne River basin reservoirs (Hetch Hetchy Reservoir, Lake Lloyd (Cherry Lake), and Lake Eleanor),
- ◇ Alameda reservoirs (Calaveras and San Antonio), and
- ◇ San Francisco Bay Peninsula reservoirs (Crystal Springs, Pilarcitos, and San Andreas).

On average, approximately 85% of the water that SFPUC delivers to its customers is derived from the Hetch Hetchy Reservoir and 15% is from local sources. (Water from Lake Lloyd and Lake Eleanor is typically used to satisfy downstream demands and not delivered to the Bay Area) (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000).

Total water storage capacity in the SFPUC water system is approximately 1,450 thousand acre-feet (TAF) (Null 2003; San Francisco Public Utilities Commission and Bay Area Water Users Association 2000). Hetch Hetchy Reservoir accounts for approximately 25% of the SFPUC storage capacity.

For the purposes of this technical memorandum, the Hetch Hetchy System is defined as the reservoirs, conveyance system and water treatment facilities located from the Sierra Nevada west to the Sunol Valley Water Treatment Plant.

ES.3 Potential Alternatives to the Hetch Hetchy Reservoir

Under the current SFPUC water system operations, water is delivered from three sources: Hetch Hetchy Reservoir (without local storage), Hetch Hetchy Reservoir after storage in a local reservoir, and local water after storage in a local reservoir. Water that is stored in local reservoirs is treated via filtration and disinfection prior to distribution. Water that is delivered directly to customers from the Hetch Hetchy Reservoir and not stored in local reservoirs is disinfected but not filtered. SFPUC is able to deliver unfiltered (surface) water because it has qualified for a filtration exemption from US EPA and the CA Department of Health Services for water stored in Hetch Hetchy Reservoir.

In the future, if the Hetch Hetchy Reservoir remains part of the water supply system, water will likely be delivered from the same three sources (although more water will need to be delivered). If the SFPUC water system is operated without the use of the Hetch Hetchy Reservoir in the future, in addition to the current sources of water, water could also be delivered from both Don Pedro Reservoir and the San Joaquin Delta. For this water quality evaluation, it is assumed that without the Hetch Hetchy Reservoir, SFPUC will not qualify for a filtration exemption, and will treat all water via filtration and disinfection prior to distribution.

Based on information supplied by Environmental Defense, potential future strategies for operating the SFPUC water system without the Hetch Hetchy Reservoir could include delivering water from 1) Don Pedro Reservoir via a direct diversion, 2) Don Pedro Reservoir after local storage, 3) the Delta via a direct diversion, and 4) the Delta after local storage. Increased storage in local reservoirs is also a strategy that could help to meet future demand. Different raw water qualities would be associated with each alternative operation of the system.

The alternatives investigated in this evaluation are those that were requested by Environmental Defense based on its hydrologic modeling. The alternatives investigated were intended to bracket the water qualities of potential future operations of the SFPUC water system both with and without the use of the Hetch Hetchy Reservoir. Not all potential alternatives were investigated, as many of the potential alternatives could be considered, from a planning level engineering perspective, to be combinations of those that were investigated. The alternatives that were investigated as part of this water quality evaluation are as follows:

- Existing (base) conditions;
- Future conditions with Hetch Hetchy Reservoir, includes expanded Calaveras Reservoir and increased demand;
- Future conditions without Hetch Hetchy Reservoir, maximizing a Don Pedro diversion;
- Future conditions without Hetch Hetchy Reservoir, maximizing a Delta diversion; and
- Future conditions without Hetch Hetchy Reservoir, using a Don Pedro diversion and an expanded Calaveras Reservoir.

ES.4 Data Employed in Water Quality Evaluation

For the purposes of this planning level summary of existing and potential future water quality, it was necessary to identify locations within the Hetch Hetchy water system at which the water quality is representative of SFPUC's raw source waters. Based on the descriptions of the sources of water that are currently employed or could be employed in the future, the raw source waters that needed to be included in this evaluation are as follows:

- Hetch Hetchy water;
- Don Pedro water;
- San Joaquin Delta water; and
- Water from local reservoirs.

Based on meetings and correspondences with SFPUC Planning Bureau and Environmental Defense staff, monitoring stations considered to be representative of the raw water sources of interest were identified. Based on those representative stations, available data were sought from appropriate agencies. SFPUC, Modesto Irrigation District, Turlock Irrigation District, the City of Modesto, Don Pedro Reservoir Recreation District, and the CA Department of Water Resources provided relevant data and information.

A comprehensive list of chemicals and microbiological contaminants that are known to have the potential to pose a risk to public health via exposure through drinking water was developed (Attachment 1). That list of contaminants of potential concern was critically reviewed and prioritized for this investigation based on the availability of monitoring data, the known public health concern associated with each of the contaminants on the list, and potential utility as an indicator of other important water quality constituents. The resultant list of contaminants for which data were sought for this planning level evaluation is presented in Table ES.1. Note that data for all contaminants were not available for all source waters.

Table ES.1 List of Contaminants Investigated During Water Quality Evaluation

Inorganic Chemicals	Organic Chemicals	Other Contaminants with Secondary MCLs	Minerals and General Parameters	Microbiological	Radionuclides
Asbestos	Methl Tertiary Butyl Ether	Chloride	Alkalinity (as CO3)	Total Coliform	Total Alpha Particle
Aluminum	Total Trihalomethanes	Color	Calcium	Fecal Coliform	Total Beta Particle
Antimony	2,4-D	Copper	Hardness (as CaCO3)	Giardia	Strontium-90
Arsenic	Aldrin	Iron	Magnesium	Cryptosporidium	Tritium
Barium	Benzo(a)pyrene	Manganese	pH	E. coli	Uranium
Berylium	Butachlor	Silver	Perchlorate		Radon-222
Cadmium	Carbaryl	Zinc	Phosphate		
Chromium	Dicamba	Foaming Agent (MBAS)	Potassium		
Cyanide	Dieldrin	Odor Threshold	Silica		
Fluoride	Dinoseb	Specific Conductance	Sodium		
Lead	Diquat	Sulfate	Boron		
Mercury	Diuron	Total Dissolved Solids	Bromide		
Nickel	Glyphosate	Turbidity	Total Organic Carbon		
Nitrate (as NO3)	3-Hydroxycarbofuran				
Nitrite (as N)	Methomyl				
Selenium	Metolachlor				
Thalium	Metribuzin				
	Oxamyl				
	Propachlor				

The data that were available for each of the raw and treated source waters were then compiled and summarized.

ES.5 Current Finished Water Quality

The specific combination of source waters that SFPUC delivers to its customers varies on both short (monthly) and longer (annual) time frames. Environmental Defense provided water supply modeling results for this water quality evaluation describing the volume of each type of water predicted to be delivered by SFPUC for a range of hydrologic conditions and current demand (average 288 Thousand acre-feet). The hydrologic conditions supplied by Environmental Defense for this evaluation include: 1) an average hydrologic year (average hydrology from 1922 to 1994), 2) average hydrologic year during drought conditions (average hydrology 1987 to 1992), 3) maximum use of upstream supply (based on 1922-1994 monthly hydrology), and 4) maximum use of local supply (based on 1922-1994 monthly hydrology).

Based on the assumed range of source water mixtures provided by Environmental Defense, a summary of predicted SFPUC delivered water quality for current demand was developed. This finished water quality was used as a baseline against which future water quality was evaluated.

ES.6 Projected Raw Water Quality for Alternative Operational Strategies

The alternative strategies for operating the SFPUC water system without the Hetch Hetchy that were investigated are as follows:

1. Future (2030) without Hetch Hetchy Reservoir maximizing Don Pedro diversion,
2. Future without Hetch Hetchy Reservoir maximizing Delta diversion, and
3. Future without Hetch Hetchy Reservoir using Don Pedro diversion and an expanded Calaveras Reservoir.

For each of the three future alternatives investigated without Hetch Hetchy Reservoir, it is assumed for the purposes of this water quality evaluation that all water delivered to SFPUC customers will be treated by filtration and disinfection.

Summaries of raw water quality (i.e. prior to filtration and disinfection) were projected for the three alternative operations of the Hetch Hetchy system described above, based on available data for current raw waters and 2030 demand levels of 330 TAF (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000). It was assumed that for each of the available raw water supplies (Hetch Hetchy (represents Tuolumne River water in this section), Don Pedro, Delta, and local water), the water quality associated with the current supply is a reasonable and representative proxy for the future supply.

ES.7 Water Treatment Options for Alternative Operational Strategies

The objective of this component of the evaluation was to identify potential and appropriate water treatment technologies for the alternatives described above that would result in water quality that is effectively equivalent to the current finished water quality.

During the 1990s, the SFPUC conducted planning studies that examined options for water treatment processes that might be required to meet current and potential future federal and state regulations. Separate treatability studies were carried out for both the Hetch Hetchy System and local (Alameda) source waters (Camp Dresser & McKee 1995a; Camp Dresser & McKee 1995b). Although the projected raw water quality conditions in the present study differ somewhat from the raw water quality conditions examined in the earlier SFPUC studies, the information developed in those studies was useful in identifying appropriate treatment for the alternatives. A study of Bay-Delta Water Quality conducted by the California Urban Water Agencies was useful in identifying water quality issues and potential treatment options for the alternative involving Delta diversion.

The proposed treatment options rely, to the extent feasible, on treatment technologies that are currently in use by the SFPUC. This is not meant to imply that "newer" technologies, such as microfiltration and UV disinfection, might not play a role in meeting treatment needs and the increasingly stringent requirements of future Rules and Regulations governing public water systems. However, for purposes of this planning level evaluation, current water treatment methods are specified with the understanding that the newer alternative technologies would be evaluated as part of more detailed studies carried out as part of the engineering design of new facilities.

Depending on the mix of source waters that would be employed in the future without the use of the Hetch Hetchy Reservoir, the potential range of water treatment that would be required to deliver water that is of similar quality to that currently delivered, is broad. For example, direct filtration (which would include preoxidation followed by coagulation/flocculation, filtration, and chloramination) may be an appropriate treatment scheme to treat Don Pedro or "run of the river" Tuolumne River water. Whereas, San Joaquin Delta water would likely require full conventional treatment (preoxidation, enhanced coagulation/flocculation, sedimentation, filtration, and chloramination) followed by a nanofiltration or reverse osmosis process on at least part of the raw water.

To optimize overall treatment costs and process flexibility, and to more closely match treatment processes to source water characteristics, separate treatment capabilities for "upstream" sources

(Tuolumne River from upstream and Don Pedro direct diversion) and for Local Storage sources may be desirable.

ES.8 Conclusions

From a screening level water quality perspective, there does not appear to be any technical reason that the SFPUC Hetch Hetchy water supply system could not be operated without the Hetch Hetchy Reservoir provided that adequate water treatment facilities were put in place and operated to meet state and federal drinking water regulations. If such an operational strategy were to be pursued, future engineering and health effects investigations would be needed to optimize water quality and treatment issues. Further, in a restored Hetch Hetchy Valley watershed practices would have to be developed, implemented and enforced to minimize the potential contamination of source waters associated with increased human and animal presence.

The analysis presented herein is as comprehensive as possible given the available information and data. Nevertheless, it should be clear that there are limitations to this type of evaluation, primarily those associated with limitations of the existing data Further, it cannot be overemphasized that the financial, water supply, and political ramifications of operating the SFPUC water system without the Hetch Hetchy Reservoir are beyond the scope of this planning level water quality evaluation.

Water Quality Evaluation for Hetch Hetchy Reservoir Alternatives

1.0 Introduction

1.1 Purpose and Scope

Environmental Defense is investigating the feasibility of restoring the Hetch Hetchy Valley (Figure 1.1) and is therefore exploring alternatives for the water supply, water quality and power benefits currently made possible by the Hetch Hetchy Reservoir. For that purpose, a planning level study is being carried out to investigate the potential technical, operational, and political considerations associated with alternative operations of the City's water and power systems. The purpose of this technical memorandum is to provide a planning level summary of existing and potential future water quality both with and without the Hetch Hetchy Reservoir for alternatives being investigated by Environmental Defense.

Figure 1.1 Hetch Hetchy Valley Prior to 1913

(Figure reference: http://www.cr.nps.gov/history/online_books/story/story41.htm)

This planning-level water quality evaluation is comprised of five tasks:

- ◇ Summarize existing operations of the San Francisco Public Utilities Commission (SFPUC) water system and current water quality, based on readily available information and data;
- ◇ Summarize projected future water quality both with and without the Hetch Hetchy Reservoir based on alternative operational strategies of the SFPUC water system supplied by Environmental Defense;
- ◇ Identify water treatment technologies for the alternative operational strategies that could be used to provide equivalent water quality to the existing water quality with the Hetch Hetchy Reservoir in place;

◇ Summarize the projected future water quality for the investigated alternatives with the additional water treatment technologies in place; and
◇ Discuss related issues as requested by Environmental Defense and summarize the limitations of this planning level evaluation.

1.2 Background

The San Francisco Public Utilities Commission (SFPUC) operates a water system that stretches from the Sierra Nevada west to the city of San Francisco. The SFPUC water system is comprised of the O'Shaughnessy Dam in Yosemite National Park, ten other dams and associated reservoirs, numerous water conveyance pipelines, and two major and several minor water treatment facilities. This system provides water to nearly 2.3 million people in the San Francisco Bay Area, including the City and County of San Francisco and 29 wholesale water agencies in San Mateo, Alameda, and Santa Clara Counties (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000; U.S. Bureau of Reclamation 1987).

The history of the SFPUC water system dates back to 1903, when private water rights to the Tuolumne watershed were assigned to the City of San Francisco (City) to appropriate water from the Tuolumne River at the mouth of the Hetch Hetchy Valley and at points along two of the Tuolumne's tributaries, Eleanor and Cherry Creeks. In 1913, the Raker Act was enacted by Congress outlining the provisions under which the City could construct and operate a water supply system on the Tuolumne River. The Raker Act granted the City authority to construct a water supply and hydropower system in the Hetch Hetchy and Eleanor Valleys in Yosemite National Park, Cherry Valley in the Stanislaus National Forest, and in the canyon of the Tuolumne River downstream of these valleys. The Raker Act also defined San Francisco's obligations to the Turlock and Modesto Irrigation Districts, and limited San Francisco's authority to export and distribute water.

Construction of the Tuolumne River water supply system began in 1914 and by 1918 water storage in Lake Eleanor began. The first water from Hetch Hetchy reservoir impounded behind O'Shaughnessy Dam was delivered to San Francisco in 1934. The dam was raised in 1938, giving the reservoir its present capacity of 360,360 acre-feet (CH2M HILL 1995). In 2002, San Francisco voters passed a 1.6 billion dollar bond, to be supplemented by another 2 billion dollars from suburban customers to fund a Capital Improvement Program that will repair, replace, and upgrade the water supply system and to build new and enlarged facilities to accommodate future growth. Currently, Hetch Hetchy Reservoir provides approximately 25% of SFPUC's water storage capacity (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000).

Approximately 85% of the water that SFPUC delivers to its Bay Area customers is derived from the Hetch Hetchy Reservoir, and the remaining 15% is derived from the Coast Range and Peninsula reservoirs (local supplies). Prior to distribution, local supplies and Hetch Hetchy water stored in local reservoirs are treated at two filtration plants, the Sunol Valley and the Harry Tracy Water Treatment Plants. Water that is delivered directly to customers from the Hetch Hetchy Reservoir and not stored in local reservoirs is disinfected but not filtered.

Typically, public water systems that deliver surface water or ground water under the direct influence of surface water and serve at least 10,000 people are required by federal regulations to employ filtration as part of their drinking water treatment process (U.S. EPA 2000). In fact, recent federal regulations require public water systems to meet more stringent filtration requirements to minimize the risk to public health from pathogenic microorganisms. However, public utilities can obtain a filtration exemption provided that certain water quality criteria are met. To qualify for a filtration exemption under current national drinking water regulations, the system cannot be the source of a waterborne disease outbreak, must meet source water quality limits for coliform and turbidity and meet coliform and total trihalomethane Maximum Contaminant Levels (MCLS). Disinfectant residual levels and redundant disinfection capability must also be maintained. Filtration exemptions also require that a watershed control program be implemented to minimize microbial contamination of the source water. This program must characterize the watershed's hydrology, physical features, land use, source water quality and operational capabilities. It must also identify, monitor and control manmade and naturally occurring activities that are detrimental to water quality, and be able to control activities through land ownership or written agreements (U.S. EPA 1998). Consistent with these criteria, SFPUC has qualified for a filtration exemption for water stored in the Hetch Hetchy reservoir. There are only a few other large water systems in the country(such as New York City and Seattle) that have qualified for a filtration exemption.

1.3 Operations Overview for Hetch Hetchy Water Supply System

1.3.1 SFPUC Water System Overview

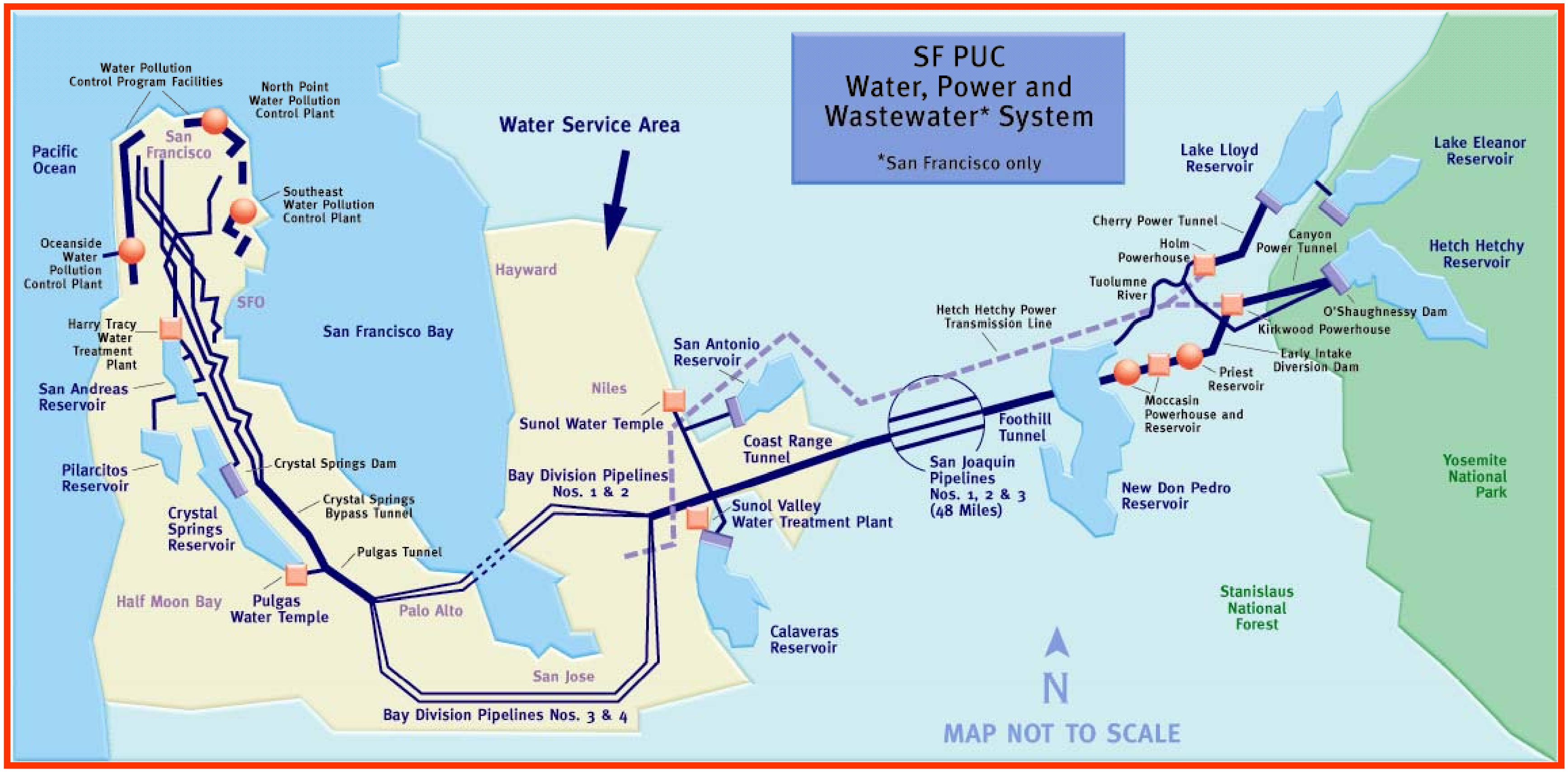
The SFPUC water supply system produces an average of approximately 300 million gallons of water per day and approximately 1.7 billion KW hrs of hydropower each year (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000; U.S. Bureau of Reclamation 1987). The water system is comprised of reservoirs in the Sierra Nevada and the Bay Area, hydroelectric generation facilities, conveyance pipelines and water treatment facilities. The system supplies water to the city and county of San Francisco, as well as parts of San Mateo, Santa Clara, and Alameda Counties. A schematic diagram of the SFPUC water system is presented in Figure 1.2.

There are three primary sources of water in the SFPUC water system (CH2M HILL 1995; San Francisco Public Utilities Commission and Bay Area Water Users Association 2000):

- ◇ Tuolumne River basin reservoirs (Hetch Hetchy Reservoir, Lake Lloyd (Cherry), and Lake Eleanor),
- ◇ Alameda reservoirs (Calaveras and San Antonio), and
- ◇ San Francisco Bay Peninsula reservoirs (Crystal Springs, Pilarcitos, and San Andreas).

On average, approximately 85% of the water that SFPUC delivers to its customers is derived from the Hetch Hetchy Reservoir and 15% is from local sources. (Water from Lake Lloyd and Lake Eleanor is typically used to satisfy downstream demands and not delivered to the Bay Area, as explained below) (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000).

Figure 1.2 Schematic Diagram of SFPUC Water System



(Figure provided by SFPUC)

Total water storage capacity in the SFPUC water system is approximately 1,450 thousand acre-feet (TAF) (Table 1.1) (Null 2003; San Francisco Public Utilities Commission and Bay Area Water Users Association 2000). Hetch Hetchy Reservoir accounts for approximately 25% of the SFPUC storage capacity.

Table 1.1. Storage Capacity in SFPUC Water System

Reservoir	Capacity (thousand acre-feet)
O'Shaughnessy	360
Eleanor	27
Cherry	273
New Don Pedro*	570
San Antonio	50
Calaveras	97
Crystal Springs	69
Pilarcitos	3
San Andreas	19
Total Storage	1468

*Space owned by the City and County of San Francisco. Total Storage in New Don Pedro Reservoir is 2,030 TAF. Approximately 1,500 TAF of storage is owned by Modesto Irrigation District and Turlock Irrigation District.

1.3.2 Hetch Hetchy Water Supply System Operations Summary

For the purposes of this technical memorandum, the Hetch Hetchy System is defined as the reservoirs, conveyance system and water treatment facilities located from the Sierra Nevada west to the Sunol Valley Water Treatment Plant. A brief overview of the Hetch Hetchy system components and operations is provided below. A schematic diagram of the Hetch Hetchy system is provided in Figure 1.3.

Tuolumne River Basin Reservoirs Hetch Hetchy Reservoir is located on the main stem of the Tuolumne River at Hetch Hetchy Valley and is formed by the water impounded by O'Shaughnessy Dam (Figure 1.4). O'Shaughnessy Dam is a 312 foot, gravity arch concrete dam with a capacity of 360,360 acre-feet. The reservoir is supplied primarily by snowmelt from a watershed of 459 square miles that is located entirely within Yosemite National Park. The water from Hetch Hetchy Reservoir is used to provide domestic water supplies within San Francisco's service area, to fulfill the SFPUC's obligations to the Turlock and Modesto Irrigation Districts and the Department of the Interior for maintenance of instream flows in the Tuolumne River below the O'Shaughnessy Dam, and to generate hydroelectric power. Of the three reservoirs in the Tuolumne River Basin, only Hetch Hetchy directly supplies water to the Bay Area under current normal operating procedures (CH2M HILL 1995).

Lake Eleanor Reservoir is located on Eleanor Creek approximately 3 miles above the confluence of Eleanor and Cherry Creeks. The reservoir is impounded by a 60-foot concrete arch dam. The reservoir's 27,100 acre-foot capacity receives water from a 79 square-mile watershed *(CH2M HILL 1995)*.

Lake Lloyd Reservoir is commonly known as Cherry Lake. The reservoir is located on Cherry Creek, about 4 miles above its confluence with Eleanor Creek, and receives water from a 114 square-mile watershed. The 268,800 acre-foot reservoir is formed by Cherry Valley Dam, a 315 foot-high earth and rockfill structure. Lake Eleanor and Lake Cherry are linked by a mile-long tunnel and are operated as a single-storage unit *(CH2M HILL 1995)*.

Figure 1.3 Schematic Diagram of Hetch Hetchy System

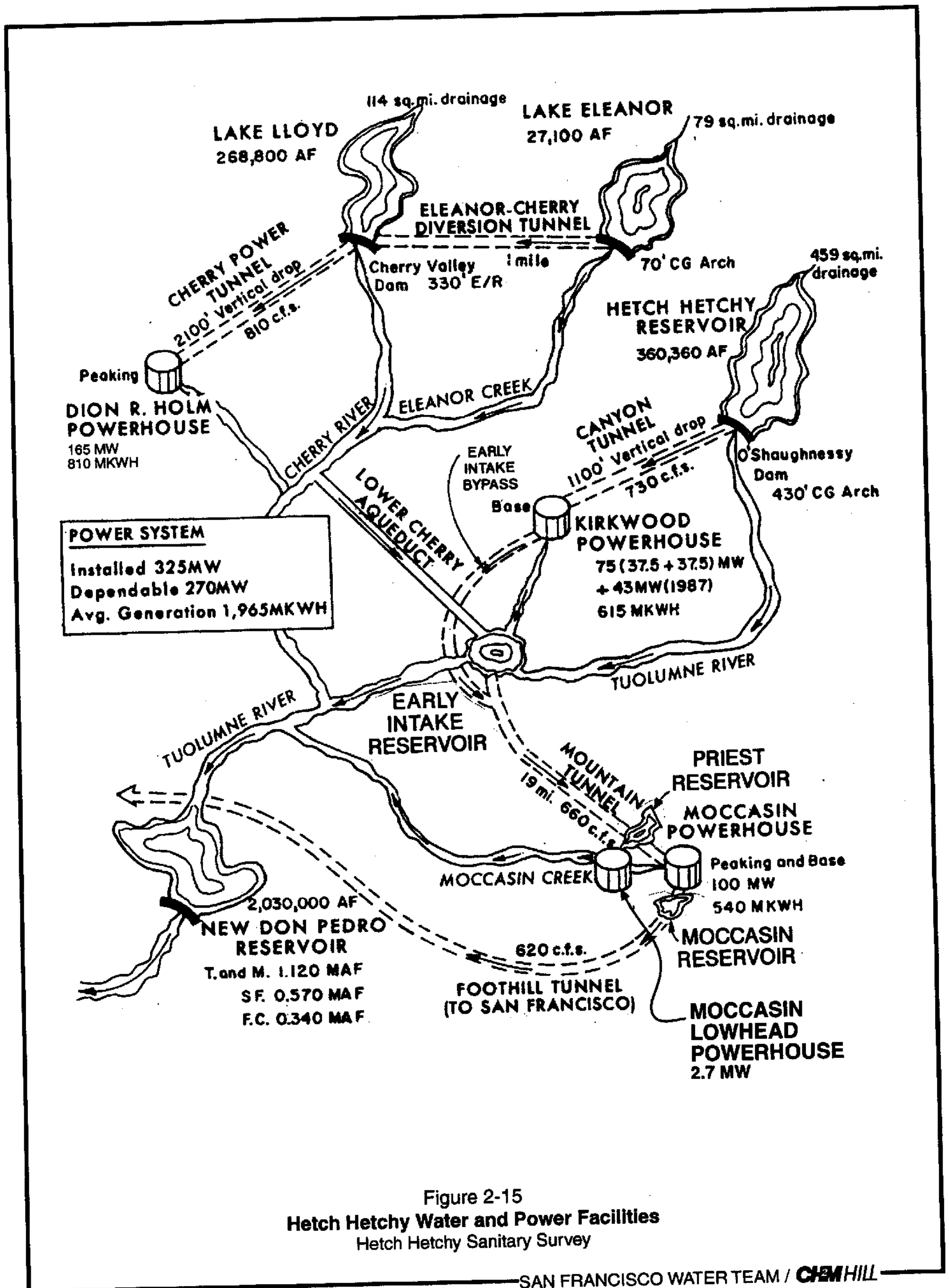


Figure 2-15
Hetch Hetchy Water and Power Facilities
Hetch Hetchy Sanitary Survey

2-35

Figure Reference: (CH2M HILL 1995)

Figure 1.4 O'Shaughnessy Dam

Figure Reference: http://www.hetchhetchy.org/oshaughnessy_dam_1998.html

Eleanor and Cherry Lakes do not normally supply water for the City's domestic uses because the Cherry River joins the Tuolumne downstream from SFPUC's diversion point for exports. (Also note that the watershed above O'Shaughnessy Dam is the only reservoir in the Hetch Hetchy System to have a filtration exemption. Although Cherry and Eleanor Lakes are less than ten miles from Hetch Hetchy Reservoir, neither qualify for a filtration exemption *(CH2M HILL 1995)*). To the extent that SFPUC can release water from Eleanor and Cherry Lakes to satisfy downstream demands, these reservoirs help maximize use of the water impounded in Hetch Hetchy Reservoir for domestic use. Except in dry years, these two lakes primarily supply water to Turlock and Modesto Irrigation Districts and provide power generation at Holm powerhouse (see below). During emergencies and droughts, water can be diverted from these lakes to Early Intake Reservoir and then rediverted into the Mountain Tunnel for transport to the Bay Area for domestic use *(CH2M HILL 1995)*. If this water were to be delivered, it would need to be filtered.

Holm and Kirkwood Hydroelectric Facilities Water that is not released from Lake Eleanor or Lake Cherry directly into the Cherry River System is diverted for generation of hydroelectric power (Figure 1.2). From Cherry Dam, water flows through the Cherry Power Tunnel to the Holm Powerhouse located on Cherry Creek about 2 miles upstream of its confluence with the Tuolumne River. After water passes through the Holm Powerhouse it is released into Cherry Creek where it then flows into the Tuolumne River.

All water from the Hetch Hetchy Reservoir first enters the Canyon Power Tunnel for hydroelectric power generation at Kirkwood powerhouse (Figure 1.2). When water leaves the Canyon Tunnel, it drops 1,100 feet through a penstock into 3 generators at Kirkwood powerhouse, which is located at Early Intake on the Tuolumne River. Part or all of the water in the Canyon Tunnel can be bypassed around the turbine directly into the Early Intake Bypass or the Tuolumne River *(CH2M HILL 1995)*.

Priest Reservoir and Moccasin Powerhouse and Reservoir From the Kirkwood Powerhouse, water is released through Early Intake bypass into Mountain Tunnel (Figure 1.2). Mountain Tunnel conveys the water 19 miles down the Sierra Nevada into Priest Regulating Reservoir. Priest Dam is an earth and rockfill dam with a capacity of 1,850 acre feet and serves as an upstream regulating reservoir for Moccasin Powerhouse.

From Priest Reservoir, water flows through Moccasin Power Tunnel, enters penstocks, and drops 1,300 feet into Moccasin Powerhouse, and then flows into Moccasin Reservoir. This reservoir is formed by the Upper and Lower Moccasin Dams and serves as a forebay to the Foothill Tunnel *(CH2M HILL 1995)*.

Conveyance System to the Bay Area Water that is to be delivered to the Bay Area flows from the Moccasin Reservoir into the Foothill Tunnel. The Foothill Tunnel runs 16 miles from Moccasin to the Oakdale Portal where it connects with the three San Joaquin Pipelines. Water that is not delivered to the Bay Area is released from Moccasin Reservoir into Moccasin Creek from which it flows into New Don Pedro Reservoir.

The San Joaquin Pipelines carry the water 47 miles across the San Joaquin Valley to Tesla Portal. From the Tesla Portal, water is conveyed 29 miles beneath the coastal mountains via the Coast Range Tunnel to Alameda East Portal, located in Fremont. The Alameda East Portal marks the end of the Hetch Hetchy System and the beginning of the Bay Area System.

Water Treatment within the Hetch Hetchy System The Rock River Lime Station is located in Chinese Camp, CA and feeds calcium hydroxide slurry into the Rock River shaft in the Foothill Tunnel for pH adjustment. The water then enters the San Joaquin Pipelines. The Tesla Portal Station is located in Tracy, CA. The Tesla Station feeds sodium hypochlorite to the Coast Range Tunnel just downstream of the San Joaquin Pipeline. Both facilities operate full time and treat all Hetch Hetchy flow. Sodium hypochlorite is supplemented in the Alameda Siphons. Downstream in the Alameda Siphons aqua ammonia is added to convert the disinfectant to chloramines. Water from the Calaveras and San Antonio Reservoirs is treated at the Sunol Valley Water Treatment Plant (SVWTP) before being conveyed into the SFPUC Bay Area System.

1.4 Overview of Potential Operational Changes for Alternatives to Hetch Hetchy Reservoir

Water that is stored in the Hetch Hetchy Reservoir and delivered directly to customers in the Bay Area (i.e. not stored in local reservoirs) is currently disinfected but not filtered. For the purposes of this water quality evaluation, it is assumed that if the Hetch Hetchy Reservoir is not used in the future, SFPUC will have to filter all of the water that is delivered to the Bay Area. Given that no other reservoir in the SFPUC water system qualified for a filtration exemption, it is conservative and reasonable to assume that a filtration exemption may not be granted for any of the existing reservoirs in the future.

The financial, water supply and political ramifications of operating the SFPUC water system without the Hetch Hetchy Reservoir are beyond the scope of this planning level water quality evaluation. However, if the Hetch Hetchy Reservoir were not part of the water supply system, it should be clear that there would be a number of possible alternative water supply strategies that the SFPUC could pursue. Each of those alternative water supply strategies will have an associated water quality, based on the mix of raw waters that would be treated and delivered. Based on information supplied by Environmental Defense, the alternative strategies for operating the SFPUC Water System without the Hetch Hetchy Reservoir can be categorized as combinations of the following components:

- ◇ Increased use of local storage in Calaveras and San Antonio Reservoirs,
- ◇ Storage of water in and delivery of water to the Bay Area from Don Pedro Reservoir; and
- ◇ Increased use of San Joaquin Delta water both via storage in local reservoirs and via a direct diversion.

Under the current SFPUC water system operations, water is delivered from three sources: Hetch Hetchy Reservoir (without local storage), Hetch Hetchy Reservoir after storage in a local reservoir, and local water after storage in a local reservoir. In the future, if the Hetch Hetchy Reservoir remains part of the water supply system, water will likely be delivered from the same three sources (although more water will need to be delivered). If the SFPUC water system is operated without the use of the Hetch Hetchy Reservoir in the future, in addition to the current sources of water, water could also be delivered from both Don Pedro Reservoir and the San Joaquin Delta. Based on information supplied by Environmental Defense, potential future strategies for operating the SFPUC water system without the Hetch Hetchy Reservoir could include delivering water from 1) Don Pedro Reservoir via a direct diversion, 2) Don Pedro Reservoir after local storage, 3) the Delta via a direct diversion, and 4) the Delta after local storage. As noted above, there would be different water qualities associated with each of the potential alternatives.

The alternatives investigated in this evaluation are those that were requested by Environmental Defense, based on its hydrologic modeling. The alternatives investigated were intended to bracket the water qualities of potential future operations of the SFPUC water system both with and without the use of the Hetch Hetchy Reservoir. Note that all potential alternatives are not investigated herein, as many of the potential alternatives could be considered, from a planning level engineering perspective, to be combinations of those investigated herein. The alternatives that were investigated as part of this water quality evaluation are as follows:

- ◇ Existing (base) conditions;
- ◇ Future conditions with Hetch Hetchy Reservoir, includes Calaveras Reservoir and increased demand;
- ◇ Future conditions without Hetch Hetchy Reservoir, maximizing a Don Pedro diversion,
- ◇ Future conditions without Hetch Hetchy Reservoir, maximizing a Delta diversion; and
- ◇ Future conditions without Hetch Hetchy Reservoir, using a Don Pedro diversion and an expanded Calaveras Reservoir.

A summary of the volume of water that is predicted by Environmental Defense's Tuolumne River Equivalent Water Supply simulation Model (TREWSSIM) to be delivered under each of the above strategies for an average hydrologic year (average hydrology from 1922 to 1994) and for an average hydrologic year during drought conditions (average hydrology 1987 to 1992) is presented in Table 1.2. As shown in Table 1.2, TREWSSIM estimates that 288 thousand acre-feet (TAF) are currently delivered in an average year and that 262 TAF are delivered during a drought year. The principal water supply difference between average and drought years under current demand is that less local water is delivered in drought years.

Table 1.2. Volume of Water Assumed to be Delivered by SFPUC under Investigated Alternatives

(Units of Thousands of Acre-Feet)

	Existing-Base		Future With Reservoir		Future Without Reservoir Maximize Don Pedro Diversion		Future Without Reservoir Using Don Pedro and Expanded Calaveras		Future Without Reservoir Maximize Delta Diversion	
Source	Average	Drought	Average	Drought	Average	Drought	Average	Drought	Average	Drought
Local Water From Local Storage	34	15	39	62	35	30	29	23	29	23
Tuolumne River Water After Local Storage	12	8	60	125	17	14	29	22	29	22
Tuolumne River Water From Upstream	242	240	240	152	161	130	153	129	153	129
Don Pedro Water After Local Storage	0	0	0	0	6	5	13	10	0	0
Don Pedro Direct Diversion	0	0	0	0	121	161	115	156	0	0
Delta Water After Local Storage	0	0	0	0	0	0	0	0	13	10
Delta Direct Diversion	0	0	0	0	0	0	0	0	115	156
Total	288	262	339	339	339	339	339	339	339	339

1. Source of Data for Table: Environmental Defense TREWSSIM
2. Under "Existing" and "Future with Resevoir", Tuolumne River water from upstream is first stored in Hetch Hetchy Reservoir,
3. Future Demand = Year 2030 (SFPUC, 2000, Water Supply Master Plan)
4. Average Year = average hydrology from 1922 to 1994
5. Drought Year = average hyrology 1987 to 1992

Future (2030) demand is estimated by SFPUC to be 339 TAF (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000). Table 1.2 indicates that with the Hetch Hetchy Reservoir, the increased future demand would be met in an average year primarily by storing more Hetch Hetchy water in local reservoirs (60 TAF) compared to existing conditions (12 TAF). Future demand under drought conditions would be met by delivering a substantially increased volume of Hetch Hetchy water after local storage (125 TAF) and an increased volume of local water (62 TAF).

Under the three alternative operations without the use of the Hetch Hetchy Reservoir, future demand of 339 TAF is met by delivering substantially different volumes of water from each of the sources. Under the alternative in which a Don Pedro diversion is maximized, 127 TAF of water from Don Pedro would be delivered (6 TAF after local storage) in an average year and 166 TAF from Don Pedro would be delivered in a drought year. Under the alternative in which a Delta diversion is maximized, 128 TAF of water from the Delta would be delivered (13 TAF after local storage) in an average year and 166 TAF from the Delta would be delivered in a drought year (10 after local storage). Under the alternative in which a Don Pedro diversion is utilized in conjunction with an expanded Calaveras Reservoir, 128 TAF of water from Don Pedro would be delivered (13 TAF after local storage) in an average year and 166 TAF would be delivered in a drought year (10 after local storage). Note for existing conditions the amount of water delivered during drought conditions is less than during an average year. However, for future conditions it is conservatively assumed the same total amount of water would be delivered during a drought year.

2.0 Data Employed in Water Quality Evaluation

2.1 Representative Monitoring Stations for Hetch Hetchy System

In Section 1, current and potential future operations of the SFPUC water system with and without the Hetch Hetchy Reservoir were introduced. From that introduction, it should be understood that 1) Under the current SFPUC water system operations, water is delivered from three sources: Hetch Hetchy Reservoir (without local storage), Hetch Hetchy Reservoir after storage in a local reservoir, and local water after storage in a local reservoir, 2) In the future, if the Hetch Hetchy Reservoir remains part of the water supply system, water will likely be delivered from the same three sources, and 3) If the SFPUC water system is operated without the use of the Hetch Hetchy Reservoir in the future, in addition to the current sources of water, water could also be delivered from both Don Pedro Reservoir (via a direct diversion or after local storage) and/or the San Joaquin Delta (via a direct diversion or after local storage).

For the purposes of this planning level summary of existing and potential future water quality, it was necessary to identify locations within the Hetch Hetchy water system at which the water quality is representative of the raw source waters to be evaluated. SFPUC staff agreed with this approach. Based on the descriptions presented above of the sources of water that are currently employed or could be employed in the future, the raw source waters that needed to be included in this evaluation were identified as follows:

- ◇ Hetch Hetchy water;
- ◇ Don Pedro water;
- ◇ San Joaquin Delta water; and
- ◇ Water from local reservoirs.

Based on meetings and correspondences with SFPUC Planning Bureau and Environmental Defense staff, monitoring stations considered to be representative of the raw water sources of interest were identified (Table 2.1). Also during those conversations, SFPUC Planning Bureau staff indicated that there are representative stations for finished (delivered) water for current operations.

Table 2.1 Monitoring Stations Representative of Water Quality in Hetch Hetchy System

Type of Water	Water Source	Representative Monitoring Station	Data Source
Raw water	Hetch Hetchy water	Hetch Hetchy Reservoir	SFPUC
		Moccasin Reservoir	SFPUC
	Don Pedro water	Don Pedro Reservoir	SFPUC
		Modesto Reservoir	MID
	Delta water	South Bay Aquaduct	SFPUC
		Banks Pumping Plant on CA Aqueduct	DWR
	Bay Area Reservoir water	Calaveras Reservoir	SFPUC
Finished water	Hetch Hetchy Treated water	Alameda East	SFPUC
	Local Treated water	Sunol Valley Water Treatment Plant Effluent	SFPUC

2.2 Contaminants Upon Which the Water Quality Evaluation is Based

The evaluation of current and potential future water quality in this technical memorandum is based on data from the representative monitoring stations described above (Table 2.1). Based on those representative stations, available data were sought from appropriate agencies. Agencies that were contacted included SFPUC, Modesto Irrigation District, Turlock Irrigation District, the City of Modesto, Don Pedro Reservoir Recreation District, and the CA Department of Water Resources.

The first step in identifying contaminants of potential concern was to develop a list of chemical and microbial contaminants that are known to have the potential to pose a risk to public health via exposure through drinking water. The list was developed by compiling chemical and microbial contaminants from the following sources:

- ◇ Constituents regulated under the Federal Drinking Water Standards (MCL FED);
- ◇ Constituents regulated under the California Safe Drinking Water Standards (MCL CA);
- ◇ The Comprehensive Response, Compensation, and Liability Administration (CERCLA) Priority List of Hazardous Substances;
- ◇ Federal Priority Pollutants (PP);
- ◇ The NPDWS Candidate Contaminant List (CCL);
- ◇ Codex Alimentarius Pesticides (Codex);
- ◇ Intergovernmental Forum on Chemical Safety (IFCS);
- ◇ Pharmaceutical Manufacturing Point Source Category (Part 439); and,
- ◇ The World Health Organization (WHO) Environmental Health Criteria Series.

The CERCLA Priority List prioritizes substances most commonly found at superfund sites. The CCL contains two parts derived from 40CFR parts 141 and 142: Contaminant Monitoring Regulation for Public Water Systems and the Unregulated Contaminant Monitoring List. Codex has created a list of acceptable residual levels for several pesticides for certain food commodities. The Pharmaceutical Manufacturing Point Source Category lists limitations set by the federal government for Pharmaceutical Manufacturers.

The compiled list of chemicals and contaminants of concern was intended to highlight constituents that have been identified from readily available lists and sources as potentially relevant to water quality monitoring. This extensive list of contaminants of possible concern contains over 750 constituents and is included in the Technical Memorandum as Attachment 1.

In collaboration with SFPUC staff, the list of contaminants of potential concern was critically reviewed and prioritized for this investigation based on the availability of monitoring data and the known public health concern associated with the contaminant list described above. The resultant list of contaminants, for which data were sought for this planning level evaluation is presented in Table 2.2.

Table 2.2 List of Contaminants Investigated During Water Quality Evaluation

Inorganic Chemicals	Organic Chemicals	Other Contaminants with Secondary MCLs	Minerals and General Parameters	Microbiological	Radionuclides
Asbestos	Methl Tertiary Butyl Ether	Chloride	Alkalinity (as CO3)	Total Coliform	Total Alpha Particle
Aluminum	Total Trihalomethanes	Color	Calcium	Fecal Coliform	Total Beta Particle
Antimony	2,4-D	Copper	Hardness (as CaCO3)	Giardia	Strontium-90
Arsenic	Aldrin	Iron	Magnesium	Cryptosporidium	Tritium
Barium	Benzo(a)pyrene	Manganese	pH	E. coli	Uranium
Berylium	Butachlor	Silver	Perchlorate		Radon-222
Cadmium	Carbaryl	Zinc	Phosphate		
Chromium	Dicamba	Foaming Agent (MBAS)	Potassium		
Cyanide	Dieldrin	Odor Threshold	Silica		
Fluoride	Dinoseb	Specific Conductance	Sodium		
Lead	Diquat	Sulfate	Boron		
Mercury	Diuron	Total Dissolved Solids	Bromide		
Nickel	Glyphosate	Turbidity	Total Organic Carbon		
Nitrate (as NO3)	3-Hydroxycarbofuran				
Nitrite (as N)	Methomyl				
Selenium	Metolachlor				
Thalium	Metribuzin				
	Oxamyl				
	Propachlor				

2.3 Overview of Data Available for Water Quality Evaluation

The data that were available for this evaluation of the raw and treated waters outlined above are summarized below. In each of the data summary tables presented below, the following data are presented:

- ◇ The total number of observations;
- ◇ The number of observations that were reported below detectable limits;
- ◇ The average concentration;
- ◇ The standard deviation of the observed concentrations;
- ◇ The time period covered by the observed data, and
- ◇ The data source.

In computing the concentration averages and standard deviations, a health protective assumption was made that all observations reported below detectable limits were assumed to be present at the corresponding detection limit. For several constituents including pH, total coliform, fecal coliform, and turbidity median values are reported rather than averages, as average values are known to be biased estimates of central tendency for data which are not normally distributed.

2.3.1 Analytical Methods and Issues

As indicated in Table 2.1, data were compiled for this investigation from three different agencies representing eight different monitoring stations. These data were employed to characterize and/or project treated and raw water qualities throughout the SFPUC water system. Water quality summaries for each of the water sources are presented below in Sections 2.3.2 through 2.3.7.

The data that were available for this investigation varied from agency to agency and between monitoring stations. In some cases, different analytical methods were employed for an individual constituent by the various agencies, and in other cases the same analytical method may have been used, but different analytical detection limits were employed. The result of the data collection effort for this investigation is a dataset comprising all of the available data for the SFPUC water system, with several important limitations. One important limitation is that in some cases few data points were available for a particular constituent at a particular site. A related limitation is that many of the reported observations were reported below detectable limits with those detection limits varying between monitoring stations. A third important limitation is that there may be constituents of potential concern that were not monitored, and therefore were not evaluated in this investigation[1]. Although little can be done to correct for the limitations in the available data, additional caution in interpreting the results is warranted given the uncertainties and limitations associated with the available data.

2.3.2 Hetch Hetchy Raw Water

Two data monitoring stations with available data were recommended to characterize Hetch Hetchy raw water. Those monitoring stations are the Hetch Hetchy Reservoir station and the Moccasin Reservoir station, both of which are monitored by SFPUC. A summary of the data that were available from SFPUC for the Hetch Hetchy Reservoir station is presented in Tables 2.3a and 2.3b, and a summary of the data that were available from SFPUC for the Moccasin Reservoir station is presented in Tables 2.4a and 2.4b. One additional monitoring station, Tesla Portal, is referenced in the Hetch Hetchy Reservoir station Table 2.3b. This station which is downstream of Hetch Hetchy and Moccasin Reservoirs was considered to be representative of the Hetch Hetchy raw water only for giardia and cryptosporidium concentrations.

[1] For example, epidemiological evidence suggests that it is possible that human enteric viruses may be an important constituent relative to raw drinking water quality. However, those viruses are difficult and expensive to monitor, therefore most drinking water agencies, consistent with State and federal guidelines monitor for bacterial indicator organisms rather than pathogenic human enteric viruses. Although this practice is commonplace, it highlights the fact that not all constituents of potential concern are commonly monitored.

Table 2.3a Data Summary for Hetch Hetchy Reservoir Station (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Asbestos	MFL	7	7	0.2	0	1997-2003	(a)
Aluminum	ug/L	9	1	82	95	1995-2003	(a)
Antimony	ug/L	9	9	5.1	0.3	1995-2003	(a)
Arsenic	ug/L	9	9	3.8	6.1	1995-2003	(a)
Barium	ug/L	0	0	NA	NA	NA	NA
Berylium	ug/L	9	9	1	0	1995-2003	(a)
Cadmium	ug/L	9	9	1	0	1995-2003	(a)
Chromium	ug/L	9	9	2.6	2.8	1995-2003	(a)
Cyanide	ug/L	3	3	0.1	0	1997-1999	(a)
Fluoride	mg/L	9	8	0.09	0.02	1995-2003	(a)
Lead	ug/L	9	9	1.7	0.5	1995-2003	(a)
Mercury	ug/L	9	9	0.6	0.2	1995-2003	(a)
Nickel	ug/L	9	9	6.1	9.4	1995-2003	(a)
Nitrate (as NO_3)	mg/L	9	9	0.5	0.6	1995-2003	(a)
Nitrite (as N)	mg/L	9	9	0.08	0.12	1995-2003	(a)
Selenium	ug/L	9	9	5	0	1995-2003	(a)
Thalium	ug/L	9	9	1	0	1995-2003	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	7	7	0.5	0	1997-2003	(a)
Total Trihalomethanes	ug/L	7	7	0.5	0	1997-2003	(a)
2,4-D	ug/L	2	2	0.1	0	2002-2003	(a)
Aldrin	ug/L	6	6	0.07	0.01	1997-2002	(a)
Benzo(a)pyrene	ug/L	6	6	0.07	0.04	1997-2002	(a)
Butachlor	ug/L	6	6	0.25	0.18	1997-2002	(a)
Carbaryl	ug/L	6	6	3.8	1.6	1997-2002	(a)
Dicamba	ug/L	6	6	0.9	0.8	1997-2002	(a)
Dieldrin	ug/L	6	6	0.02	0.01	1997-2002	(a)
Dinoseb	ug/L	6	6	1.3	1.0	1997-2002	(a)
Diquat	ug/L	6	6	2.6	2.0	1997-2002	(a)
Diuron	ug/L	0	0	NA	NA	NA	NA
Glyphosate	ug/L	2	2	6	0	2002-2003	(a)
3-Hydroxycarbofuran	ug/L	6	6	2.6	0.6	1997-2002	(a)
Methomyl	ug/L	6	6	1.6	0.6	1997-2002	(a)
Metolachlor	ug/L	5	5	0.3	0.3	1997-2002	(a)
Metribuzin	ug/L	5	5	0.3	0.3	1997-2002	(a)
Oxamyl	ug/L	6	6	12.8	9.9	1997-2002	(a)
Propachlor	ug/L	6	6	0.3	0.3	1997-2002	(a)
Radionuclides							
Total Alpha Particle	pCi/L	7	7	1	0	1997-2003	(a)
Total Beta Particle	pCi/L	7	7	4	0	1997-2003	(a)
Strontium-90	pCi/L	7	7	2	0	1997-2003	(a)
Tritium	pCi/L	7	7	715	487	1997-2003	(a)
Uranium	pCi/L	7	7	2	0	1197-2003	(a)
Radon-222	pCi/L	2	2	100	0	2002-2003	(a)

Table 2.3b Data Summary for Hetch Hetchy Reservoir Station (cont'd) (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Constituents With Secondary MCLs							
Chloride	mg/L	9	9	2.7	0.8	1995-2003	(a)
Color	units	7	0	7.9	1.9	1995-2003	(a)
Copper	ug/L	9	9	6.6	16.3	1995-2003	(a)
Foaming Agent (MBAS)	mg/L	1	1	0.5	0	1997	(a)
Iron	ug/L	9	4	30.4	27.4	1995-2003	(a)
Manganese	ug/L	9	8	5.7	9.1	1995-2003	(a)
Odor Threshold	TON	1	1	1	0	1997	(a)
Silver	ug/L	9	9	2	3	1995-2003	(a)
Specific Conductance	uS/cm	7	0	10.4	2.7	1997-2003	(a)
Sulfate	mg/L	9	4	0.6	0.3	1995-2003	(a)
Total Dissolved Solids	mg/L	9	2	11	5	1995-2003	(a)
Turbidity	NTU	9	0	0.3	-	1995-2003	(a)
Zinc	ug/L	9	9	9	15.4	1995-2003	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	9	0	4.67	0.87	1995-2003	(a)
Calcium	mg/L	9	4	1.41	0.91	1995-2003	(a)
Hardness (as $CaCO_3$)	mg/L	9	0	3.33	1	1995-2003	(a)
Magnesium	mg/L	9	9	0.36	0.17	1995-2003	(a)
pH	units	9	0	7.4	-	1995-2003	(a)
Perchlorate	ug/L	6	6	4	0	1995-2003	(a)
Phosphate	mg/L	9	9	0.06	0.02	1995-2003	(a)
Potassium	mg/L	9	7	0.39	0.16	1995-2003	(a)
Silica	mg/L	9	1	3.5	0.93	1995-2003	(a)
Sodium	mg/L	9	9	3	0	1995-2003	(a)
Boron	ug/L	1	0	8	0	2003	(a)
Bromide	mg/L	0	0	NA	NA	NA	NA
Total Organic Carbon	mg/L	160	0	1.4	0.2	1997-2000, 2002-2003	(a)
Microbiological							
Total Coliform	MPN/100ml	114	21	11	-	1/90-5/93	(b)
	MPN/100ml	105	25	2	-	1/01-12/02	(c)
Fecal Coliform	MPN/100ml	105	100	2	-	1/01-12/02	(c)
Giardia	cysts/L	5	4	0.16	0.19	5/01-8/03	(d)
	cysts/L	156	134	0.04	0.09	1/01-3/04	(e)
Cryptosporidium	oocysts/L	5	4	0.08	0.04	5/01-8/03	(d)
	oocysts/L	156	150	0.04	0.04	1/01-3/04	(e)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) 1995 Sanitary Survey Report Appendix M
(c) SFPUC excel data file for O'Shaugnessy Diversion Tunnel
(d) SFPUC excel data file for Tuolumne River just upstream of Hetch Hetchy Reservoir
(e) SFPUC website for Tesla Portal
(f) Median values reported for pH, turbidity, total coliform, and fecal coliform

Table 2.4a Data Summary for Moccasin Reservoir Station (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Asbestos	MFL	0	0	NA	NA	NA	NA
Aluminum	ug/L	4	0	43	11	2000-2003	(a)
Antimony	ug/L	4	4	5	0	2000-2003	(a)
Arsenic	ug/L	4	4	1.8	0.5	2000-2003	(a)
Barium	ug/L	4	4	5	0	2000-2003	(a)
Berylium	ug/L	4	4	1	0	2000-2003	(a)
Cadmium	ug/L	4	4	1	0	2000-2003	(a)
Chromium	ug/L	4	4	1.3	0.5	2000-2003	(a)
Cyanide	ug/L	0	0	NA	NA	NA	NA
Fluoride	mg/L	4	4	0.1	0	2000-2003	(a)
Lead	ug/L	4	4	1.8	0.5	2000-2003	(a)
Mercury	ug/L	4	4	0.5	0	2000-2003	(a)
Nickel	ug/L	4	4	1.5	1	2000-2003	(a)
Nitrate (as NO_3)	mg/L	4	3	0.2	0	2000-2003	(a)
Nitrite (as N)	mg/L	4	4	0.02	0	2000-2003	(a)
Selenium	ug/L	4	4	5	0	2000-2003	(a)
Thalium	ug/L	4	4	1	0	2000-2003	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	4	4	0.5	0	2000-2003	(a)
Total Trihalomethanes	ug/L	4	4	0.5	0	2000-2003	(a)
2,4-D	ug/L	0	0	NA	NA	NA	NA
Aldrin	ug/L	3	3	0.05	0	2000-2002	(a)
Benzo(a)pyrene	ug/L	3	3	0.02	0	2000-2002	(a)
Butachlor	ug/L	3	3	0.05	0	2000-2002	(a)
Carbaryl	ug/L	3	3	2	0	2000-2002	(a)
Dicamba	ug/L	3	3	0.08	0	2000-2002	(a)
Dieldrin	ug/L	3	3	0.01	0	2000-2002	(a)
Dinoseb	ug/L	3	3	0.2	0	2000-2002	(a)
Diquat	ug/L	3	3	0.4	0	2000-2002	(a)
Diuron	ug/L	0	0	NA	NA	NA	NA
Glyphosate	ug/L	2	2	6	0	2002-2003	(a)
3-Hydroxycarbofuran	ug/L	0	0	NA	NA	NA	NA
Methomyl	ug/L	3	3	1	0	2000-2002	(a)
Metolachlor	ug/L	3	3	0.05	0	2000-2002	(a)
Metribuzin	ug/L	3	3	0.05	0	2000-2002	(a)
Oxamyl	ug/L	3	3	2	0	2000-2002	(a)
Propachlor	ug/L	3	3	0.05	0	2000-2002	(a)
Radionuclides							
Total Alpha Particle	pCi/L	2	2	1	0	2002-2003	(a)
Total Beta Particle	pCi/L	2	2	4	0	2002-2003	(a)
Strontium-90	pCi/L	2	2	2	0	2002-2003	(a)
Tritium	pCi/L	2	2	1000	0	2002-2003	(a)
Uranium	pCi/L	2	2	2	0	2002-2003	(a)
Radon-222	pCi/L	2	2	100	0	2002-2003	(a)

Table 2.4b Data Summary for Moccasin Reservoir Station (cont'd) (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Constituents with Secondary MCLs							
Chloride	mg/L	4	4	3.0	0	2000-2003	(a)
Color	units	4	0	11	1.0	2000-2003	(a)
Copper	ug/L	4	0	7.5	3	2000-2003	(a)
Foaming Agent (MBAS)	mg/L	0	0	NA	NA	NA	NA
Iron	ug/L	4	0	59	14	2000-2003	(a)
Manganese	ug/L	4	0	4.5	1	2000-2003	(a)
Odor Threshold	TON	0	0	NA	NA	NA	NA
Silver	ug/L	4	4	1.0	0	2000-2003	(a)
Specific Conductance	uS/cm	4	0	14	2	2000-2003	(a)
Sulfate	mg/L	4	0	0.7	0.2	2000-2003	(a)
Total Dissolved Solids	mg/L	4	1	9.5	3.4	2000-2003	(a)
Turbidity	NTU	4	0	0.4	-	2000-2003	(a)
Zinc	ug/L	4	1	12.8	9.0	2000-2003	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	4	0	5.3	0.5	2000-2003	(a)
Calcium	mg/L	4	0	1.0	0	2000-2003	(a)
Hardness (as $CaCO_3$)	mg/L	4	0	4.8	0.5	2000-2003	(a)
Magnesium	mg/L	4	3	0.4	0.2	2000-2003	(a)
pH	units	4	0	6.8	-	2000-2003	(a)
Perchlorate	ug/L	2	2	2.0	0	2000-2001	(a)
Phosphate	mg/L	4	4	0.07	0	2000-2003	(a)
Potassium	mg/L	4	4	0.5	0	2000-2003	(a)
Silica	mg/L	4	0	4.5	0.6	2000-2003	(a)
Sodium	mg/L	4	4	3.0	0	2000-2003	(a)
Boron	ug/L	1	0	9.0	0	2003	(a)
Bromide	mg/L	0	0	NA	NA	NA	NA
Total Organic Carbon	mg/L	0	0	NA	NA	NA	NA
Microbiological							
Total Coliform	MPN/100ml	2650	67	17	-	1/94-11/95;1/97-11/03	(b)
Fecal Coliform	MPN/100ml	2649	883	2	-	1/94-11/95;1/97-11/03	(b)
Giardia	cysts/L	10	6	0.01	0	8/03-2/04	(c)
Cryptosporidium	oocysts/L	10	8	0.01	0	8/03-2/04	(c)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) SFPUC Sanitary Survey Reports for Moccasin Outlet Tower
(c) SFPUC excel data file for Moccasin Gate Tower
(d) median values reported for pH, turbidity, total coliform, and fecal coliform

2.3.3 Don Pedro Raw Water

Two data monitoring stations with available data were recommended to characterize Don Pedro raw water. Those monitoring stations are the Don Pedro Reservoir station which is monitored by SFPUC, and the Modesto Reservoir station which is monitored by Modesto Irrigation District (MID). The Modesto Reservoir is a small reservoir (37 TAF) located approximately 10 miles from the Don Pedro Reservoir that is used primarily to receive and redistribute water from the Don Pedro Reservoir.

A summary of the data that were available from SFPUC for the Don Pedro Reservoir station is presented in Table 2.5, and a summary of the data that were available from MID for the Modesto Reservoir station is presented in Table 2.6.

Table 2.5 Data Summary for Don Pedro Station (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Asbestos	MFL	0	0	NA	NA	NA	NA
Aluminum	ug/L	6	0	112	56	1995-2000	(a)
Antimony	ug/L	6	6	5.2	0.4	1995-2000	(a)
Arsenic	ug/L	6	5	2	0	1995-2000	(a)
Barium	ug/L	6	0	26	36	1995-2000	(a)
Berylium	ug/L	6	6	1	0	1995-2000	(a)
Cadmium	ug/L	6	6	1	0	1995-2000	(a)
Chromium	ug/L	6	6	3.3	3.3	1995-2000	(a)
Cyanide	ug/L	0	0	NA	NA	NA	NA
Fluoride	mg/L	6	6	0.09	0.02	1995-2000	(a)
Lead	ug/L	6	6	2.2	1.5	1995-2000	(a)
Mercury	ug/L	6	6	0.7	0.3	1995-2000	(a)
Nickel	ug/L	6	6	4.2	2.9	1995-2000	(a)
Nitrate (as NO_3)	mg/L	6	6	0.6	0.7	1995-2000	(a)
Nitrite (as N)	mg/L	6	6	0.11	0.14	1995-2000	(a)
Selenium	ug/L	6	6	5	0	1995-2000	(a)
Thalium	ug/L	6	6	1	0	1995-2000	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	3	2	2.8	2.3	1997-2000	(a)
Total Trihalomethanes	ug/L	1	1	0.5	0	1997	(a)
Constituents with Secondary MCLs							
Chloride	mg/L	6	6	3	0	1995-2000	(a)
Color	units	4	0	23	5	1997-2000	(a)
Copper	ug/L	6	2	11	19	1995-2000	(a)
Foaming Agent (MBAS)	mg/L	0	0	NA	NA	NA	
Iron	ug/L	6	0	121	36	1995-2000	(a)
Manganese	ug/L	6	1	13	9	1995-2000	(a)
Odor Threshold	TON	0	0	NA	NA	NA	NA
Silver	ug/L	6	6	2.5	3.7	1995-2000	(a)
Specific Conductance	uS/cm	4	0	40	0.5	1997-2000	(a)
Sulfate	mg/L	6	0	2	0.4	1995-2000	(a)
Total Dissolved Solids	mg/L	6	0	31	5.4	1995-2000	(a)
Turbidity	NTU	6	0	2	-	1995-2000	(a)
Zinc	ug/L	6	5	13	18	1995-2000	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	6	0	18	2.1	1995-2000	(a)
Calcium	mg/L	6	0	4	0.5	1995-2000	(a)
Hardness (as $CaCO_3$)	mg/L	6	0	17	1.4	1995-2000	(a)
Magnesium	mg/L	6	0	1.9	0.3	1995-2000	(a)
pH	units	6	0	8.4	-	1995-2000	(a)
Perchlorate	ug/L	0	0	NA	NA	NA	
Phosphate	mg/L	6	5	0.05	0	1995-2000	(a)
Potassium	mg/L	6	2	0.54	0.1	1995-2000	(a)
Silica	mg/L	6	0	7.0	0.4	1995-2000	(a)
Sodium	mg/L	6	6	3	0	1995-2000	(a)
Microbiological							
Total Coliform	MPN/100ml	107	10	13	-	6/94-5/03	(b)
Fecal Coliform	MPN/100ml	50	20	2	-	3/99-5/03	(b)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) SFPUC excel data file received via email
(c) Median values reported for pH, turbidity, total coliform, and fecal coliform

Table 2.6 Data Summary for Modesto Reservoir Station (Source MID)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	0	0	NA	NA	NA	NA
Total Trihalomethanes	ug/L	5	5	0.5	0.0	1992-1995	(a,b)
2,4-D	ug/L	1	1	2		1992-1995	(a)
Aldrin	ug/L	3	3	0.023	0.023	1992-1995	(a)
Benzo(a)pyrene	ug/L	2	2	0.1	0	1992-1995	(a)
Butachlor	ug/L	2	2	1	0	1992-1995	(a)
Carbaryl	ug/L	3	3	5	0	1992-1995	(a)
Dicamba	ug/L	0	0	NA	NA	NA	NA
Dieldrin	ug/L	3	3	0.023	0.023	1992-1995	(a)
Dinoseb	ug/L	2	2	1	0	1992-1995	(a)
Diquat	ug/L	2	2	1.25	1.06	1992-1995	(a)
Diuron	ug/L	2	2	0.1	0	1992-1995	(a)
Glyphosate	ug/L	1	1	20		1992-1995	(a)
3-Hydroxycarbofuran	ug/L	3	3	10	0	1992-1995	(a)
Methomyl	ug/L	3	3	5	0	1992-1995	(a)
Metolachlor	ug/L	2	2	1	0	1992-1995	(a)
Metribuzin	ug/L	2	2	0.1	0	1992-1995	(a)
Oxamyl	ug/L	3	3	5	0	1992-1995	(a)
Propachlor	ug/L	2	2	1	0	1992-1995	(a)
Total Organic Carbon	mg/L	1	1	0.5	NA	1992	(a)
Microbiological							
Total Coliform	MPN/100ml	2601	450	4	-	1/97-3/04	(c)
Fecal Coliform	MPN/100ml	2599	1078	2	-	1/97-3/04	(c)
Giardia	cysts/L	62	60	0.10	0.01	5/98-2/04	(c)
Cryptosporidium	oocysts/L	71	61	0.11	0.05	5/98-2/04	(c)

Footnotes:
(a) MID laboratory reports
(b) One sample from 1992 not used in analysis, possible QA issue, reported 635ug/L Chloroform
(c) MID electronic file received via email
(d) Median values reported for total coliform and fecal coliform

Note that no data were available for inorganic constituents, radionuclides, constituents with secondary MCLs, minerals, or other general parameters.

2.3.4 San Joaquin Delta Raw Water

Two data monitoring stations with available data were recommended to characterize San Joaquin Delta water that could be used by SFPUC as a raw source water. Those monitoring stations are the South Bay Aqueduct station which is monitored by SFPUC, and the Banks Pumping Plant station on the California Aqueduct which is monitored by the CA Department of Water Resources (DWR). A portion of water from the California Aqueduct is directed to the South Bay Aqueduct (California Department of Water Resources 2001).

A summary of the data that were available from SFPUC for the South Bay Aqueduct station is presented in Table 2.7, and a summary of the data that were available from DWR for the Banks Pumping Plant station on the California Aqueduct is presented in Tables 2.8a and 2.8b. Additional data available from the Banks Pumping Plant station not used in this analysis is presented in Attachment 2.

Table 2.7 Data Summary for South Bay Aqueduct Station (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Asbestos	MFL	0	0	NA	NA	NA	NA
Aluminum	ug/L	6	0	215	297	1995-2000	(a)
Antimony	ug/L	6	6	5	0	1995-2000	(a)
Arsenic	ug/L	6	0	5	4	1995-2000	(a)
Barium	ug/L	6	0	130	109	1995-2000	(a)
Berylium	ug/L	6	6	1	0	1995-2000	(a)
Cadmium	ug/L	6	6	1	0	1995-2000	(a)
Chromium	ug/L	6	6	3	3	1995-2000	(a)
Cyanide	ug/L	0	0	NA	NA	NA	NA
Fluoride	mg/L	6	3	0.13	0.05	1995-2000	(a)
Lead	ug/L	6	4	2.4	1.4	1995-2000	(a)
Mercury	ug/L	6	6	0.7	0.3	1995-2000	(a)
Nickel	ug/L	6	5	4.4	2.8	1995-2000	(a)
Nitrate (as NO_3)	mg/L	6	5	0.8	0.7	1995-2000	(a)
Nitrite (as N)	mg/L	6	6	0.11	0.14	1995-2000	(a)
Selenium	ug/L	6	6	5	0	1995-2000	(a)
Thalium	ug/L	6	6	1	0	1995-2000	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	4	4	1.1	1.3	1997-2000	(a)
Total Trihalomethanes	ug/L	1	1	0.5	0	1997	(a)
Contaminatns with Secondary MCLs							
Chloride	mg/L	6	0	40	14	1995-2000	(a)
Color	units	4	0	45	30	1997-2000	(a)
Copper	ug/L	6	3	10	20	1995-2000	(a)
Foaming Agent (MBAS)	mg/L	0	0	NA	NA	NA	NA
Iron	ug/L	6	0	377	396	1995-2000	(a)
Manganese	ug/L	6	2	330	503	1995-2000	(a)
Odor Threshold	TON	0	0	NA	NA	NA	NA
Silver	ug/L	6	6	2.5	3.7	1995-2000	(a)
Specific Conductance	uS/cm	4	0	369	114	1997-2000	(a)
Sulfate	mg/L	6	0	15.8	6.7	1995-2000	(a)
Total Dissolved Solids	mg/L	6	0	272	153	1995-2000	(a)
Turbidity	NTU	6	0	0.5	-	1995-2000	(a)
Zinc	ug/L	6	6	12.5	18.4	1995-2000	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	6	0	86	37	1995-2000	(a)
Calcium	mg/L	6	6	1	0	1995-2000	(a)
Hardness (as $CaCO_3$)	mg/L	6	0	88	28	1995-2000	(a)
Magnesium	mg/L	6	0	14	7	1995-2000	(a)
pH	units	6	0	7.9	-	1995-2000	(a)
Perchlorate	ug/L	0	0	NA	NA	NA	
Phosphate	mg/L	6	0	0.3	0.3	1995-2000	(a)
Potassium	mg/L	6	0	1.5	0.9	1995-2000	(a)
Silica	mg/L	6	0	15	8	1995-2000	(a)
Sodium	mg/L	6	0	44	30	1995-2000	(a)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) Median values reported for turbidity and pH

Table 2.8a Data Summary for Banks Pumping Plants Station (Source DWR)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Asbestos	MFL	4	0	16	18	1995-1996	(a)
Aluminum	ug/L	2	2	10	0	2003	(a)
Antimony	ug/L	46	46	3	2	4/00-1/04	(b)
Arsenic	ug/L	109	1	2	0.5	1/95-1/04	(b)
Barium	ug/L	2	2	50	0	2003	(a)
Berylium	ug/L	46	46	1	0	4/00-1/04	(b)
Cadmium	ug/L	2	2	1	0	2003	(a)
Chromium	ug/L	109	65	4.7	1.4	1/95-1/04	(b)
Cyanide	ug/L	5	5	20	0	1995-1996	(a)
Fluoride	mg/L	109	100	0.1	0.03	1/95-1/04	(b)
Lead	ug/L	109	108	2	2	1/95-1/04	(b)
Mercury	ug/L	0	0	NA	NA	NA	NA
Nickel	ug/L	2	2	1	0	2003	(a)
Nitrate (as NO_3)	mg/L	109	0	0.62	0.37	1/95-1/04	(b)
Nitrite (as N)	mg/L	0	0	NA	NA	NA	NA
Selenium	ug/L	109	83	1.1	0.3	1/95-1/04	(b)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	48	37	1.1	0.2	1997-2004	(a)
Total THM formation potential	ug/L	60	0	459	138	1/95-1/04	(b)
2,4-D	ug/L	15	13	0.15	0.16	1995-2004	(a)
Aldrin	ug/L	15	15	0.03	0.03	1995-2004	(a)
Benzo(a)pyrene	ug/L	5	5	0.1	0	1995-2004	(a)
Butachlor	ug/L	5	5	0.4	0	1995-2004	(a)
Carbaryl	ug/L	14	14	2	0	1995-2004	(a)
Dicamba	ug/L	15	15	0.09	0.01	1995-2004	(a)
Dieldrin	ug/L	15	15	0.02	0.02	1995-2004	(a)
Dinoseb	ug/L	15	15	0.13	0.05	1995-2004	(a)
Diquat	ug/L	5	5	4	0	1995-2004	(a)
Diuron	ug/L	10	10	0.3	0	1995-2004	(a)
Glyphosate	ug/L	14	14	95	20	1995-2004	(a)
3-Hydroxycarbofuran	ug/L	14	14	2	0	1995-2004	(a)
Methomyl	ug/L	14	14	2	0	1995-2004	(a)
Metolachlor	ug/L	15	15	0.29	0.16	1995-2004	(a)
Metribuzin	ug/L	5	5	0.5	0	1995-2004	(a)
Oxamyl	ug/L	14	14	2	0	1995-2004	(a)
Propachlor	ug/L	5	5	0.5	0	1995-2004	(a)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) DWR web page water data library

Note that the Total THM data in Table 2.8a (EPA Method 502.2) represents THM formation potential rather than Total THM concentrations. The total THM data presented in the Tables 2.3 – 2.7 represent measured THM concentrations. Trihalomethane formation potential is a measure of the capacity for trihalomethanes to form when disinfectants are added in the water treatment process. Trihalomethane precursors include bromide and organic carbon, and total trihalomethane formation potential is the sum of chloroform, bromodichloromethane, dibromochloromethane, and bromoform (California Department of Water Resources 2000).

Table 2.8b Data Summary for Banks Pumping Plant Station (cont'd) (Source DWR)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Contaminants with Secondary MCLs							
Chloride	mg/L	109	0	53	36	1/95-1/04	(b)
Color	units	110	0	40.0	26	1990-1997	(a)
Copper	ug/L	108	27	3.7	3.2	1/95-1/04	(b)
Foaming Agent (MBAS)	mg/L	0	0	NA	NA	NA	NA
Iron	ug/L	109	24	23	29	1/95-1/04	(b)
Manganese	ug/L	109	14	15	9	1/95-1/04	(b)
Odor Threshold	TON	0	0	NA	NA	NA	NA
Silver	ug/L	2	2	1	0	2003	(a)
Specific Conductance	uS/cm	109	0	374	143	1/95-1/04	(b)
Sulfate	mg/L	108	0	31	13	1/95-1/04	(b)
Total Dissolved Solids	mg/L	109	0	213	79	1/95-1/04	(b)
Turbidity	NTU	85	0	11	-	1/95-1/04	(c)
Zinc	ug/L	106	98	7.7	10.5	1/95-1/04	(c)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	109	0	65	12.5	1/95-1/04	(b)
Calcium	mg/L	109	0	17	3.8	1/95-1/04	(b)
Hardness (as $CaCO_3$)	mg/L	109	0	84	20.6	1/95-1/04	(b)
Magnesium	mg/L	109	0	10.3	3.0	1/95-1/04	(b)
pH	units	45	0	7.3	-	1996-2004	(a)
Phosphate	mg/L	109	0	0.1	0.03	1/95-1/04	(b)
Sodium	mg/L	109	0	39	20	1/95-1/04	(b)
Boron	ug/L	108	26	160	120	1/95-1/04	(b)
Bromide	mg/L	109	0	159	124	1/95-1/04	(b)
Total Organic Carbon	mg/L	107	0	3.8	1.2	1/95-1/04	(b)
Microbiological							
Total Coliform	MPN/100ml	19	0	210	-	10/96-5/98	(d)
Fecal Coliform	MPN/100ml	20	0	55	-	10/96-5/98	(d)
E. Coli	MPN/100ml	19	0	13	-	10/96-5/98	(d)
Giardia	cysts/L	20	20	0.09	0.06	10/96-5/98	(d)
Cryptosporidium	oocysts/L	20	19	0.16	0.36	10/96-5/98	(d)

Footnotes:
(a) DWR web page water data library
(b) DWR web page monthly grab data
(c) DWR web page monthly grab data; it was assumed the turbidity and zinc data in the June 1999 Table were transposed and were corrected for this analysis.
(d) DWR hardcopy laboratory report data
(e) Median values reported for pH, turbidity, total coliform, fecal coliform, and E. Coli

2.3.5 Local (Bay Area) Raw Water

The Calaveras Reservoir monitoring station was recommended as the most appropriate and representative station to characterize local raw water that would be used by SFPUC as a raw source water. Data for the Calaveras Reservoir station was supplied by SFPUC.

A summary of the data that were available from SFPUC for the Calaveras Reservoir station is presented in Tables 2.9a and 2.9b.

Table 2.9a Data Summary for Calaveras Reservoir Station (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Asbestos	MFL	7	7	0.2	0	1997-2003	(a)
Aluminum	ug/L	9	0	94	150	1995-2003	(a)
Antimony	ug/L	9	9	5.1	0.3	1995-2003	(a)
Arsenic	ug/L	9	6	2	0.5	1995-2003	(a)
Barium	ug/L	9	1	68	14.7	1995-2003	(a)
Berylium	ug/L	9	9	1	0	1995-2003	(a)
Cadmium	ug/L	9	9	1	0	1995-2003	(a)
Chromium	ug/L	9	9	2.6	2.8	1995-2003	(a)
Cyanide	ug/L	3	3	0.1	0	1997-1999	(a)
Fluoride	mg/L	9	1	0.1	0.1	1995-2003	(a)
Lead	ug/L	9	8	1.7	0.5	1995-2003	(a)
Mercury	ug/L	9	9	1.4	1.5	1995-2003	(a)
Nickel	ug/L	9	7	2.1	1	1995-2003	(a)
Nitrate (as NO_3)	mg/L	9	6	1.8	3.2	1995-2003	(a)
Nitrite (as N)	mg/L	9	8	0.4	0.7	1995-2003	(a)
Selenium	ug/L	9	9	3.9	2.1	1995-2003	(a)
Thalium	ug/L	9	9	1.9	1.8	1995-2003	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	7	7	0.5	0	1997-2003	(a)
Total Trihalomethanes	ug/L	7	7	0.5	0	1997-2003	(a)
2,4-D	ug/L	0	0	NA	NA	NA	NA
Aldrin	ug/L	6	6	0.07	0.01	1997-2002	(a)
Benzo(a)pyrene	ug/L	6	6	0.1	0	1997-2002	(a)
Butachlor	ug/L	6	6	0.2	0.2	1997-2002	(a)
Carbaryl	ug/L	6	6	3.8	1.6	1997-2002	(a)
Dicamba	ug/L	6	6	0.9	0.8	1997-2002	(a)
Dieldrin	ug/L	6	6	0.016	0.005	1997-2002	(a)
Dinoseb	ug/L	6	6	1.3	1	1997-2002	(a)
Diquat	ug/L	6	6	2.6	2	1997-2002	(a)
Diuron	ug/L	1	1	1	0	2003	(a)
Glyphosate	ug/L	2	2	6	0	2002-2003	(a)
3-Hydroxycarbofuran	ug/L	6	6	2.6	0.5	1997-2002	(a)
Methomyl	ug/L	6	6	1.6	0.5	1997-2002	(a)
Metolachlor	ug/L	6	6	0.3	0.2	1997-2002	(a)
Metribuzin	ug/L	6	6	0.3	0.2	1997-2002	(a)
Oxamyl	ug/L	6	6	12.8	9.9	1997-2002	(a)
Propachlor	ug/L	6	6	0.3	0.2	1997-2002	(a)
Radionuclides							
Total Alpha Particle	pCi/L	7	7	1	0	1997-2003	(a)
Total Beta Particle	pCi/L	7	7	4	0	1997-2003	(a)
Strontium-90	pCi/L	7	7	2	0	1997-2003	(a)
Tritium	pCi/L	7	7	572	534	1997-2003	(a)
Uranium	pCi/L	7	7	2	0	1997-2003	(a)
Radon-222	pCi/L	2	2	100	0	2002-2003	(a)

Footnotes:
(a) SFPUC Sanitary Survey Reports

Table 2.9b Data Summary for Calaveras Reservoir Station (cont'd) (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Contaminants with Secondary MCLs							
Chloride	mg/L	9	0	6.2	0.8	1995-2003	(a)
	mg/L	96	0	7.0	1.9	1990;8/92-12/99	(b)
Color	units	7	0	25	18	1997-2003	(a)
Copper	ug/L	9	2	8.6	15.6	1995-2003	(a)
Foaming Agent (MBAS)	mg/L	1	0	0.5	0	1997	(a)
Iron	ug/L	9	1	76	61	1995-2003	(a)
Manganese	ug/L	9	1	10.7	9.8	1995-2003	(a)
Odor Threshold	TON	1	0	1	0	1997	(a)
Silver	ug/L	9	9	2	3	1995-2003	(a)
Specific Conductance	uS/cm	7	0	251	26	1997-2003	(a)
	umhos/cm	96	0	238	37	1990;8/92-12/99	(b)
Sulfate	mg/L	9	0	20	2.9	1995-2003	(a)
Total Dissolved Solids	mg/L	9	0	149	22	1995-2003	(a)
	mg/L	99	0	148	35.1	1990;8/92-12/99	(b)
Turbidity	NTU	9	0	0.8	-	1995-2003	(a)
	NTU	96	0	3.7	-	1990;8/92-12/99	(b)
Zinc	ug/L	9	9	9	15.4	1995-2003	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	9	0	101	10.8	1995-2003	(a)
	mg/L	95	0	96	16	1990;8/92-12/99	(b)
Calcium	mg/L	9	0	27.2	3.6	1995-2003	(a)
Hardness (as $CaCO_3$)	mg/L	9	0	107	10.8	1995-2003	(a)
	mg/L	96	0	104	14	1990;8/92-12/99	(b)
Magnesium	mg/L	9	0	9.5	1.3	1995-2003	(a)
pH	units	9	0	8.5	-	1995-2003	(a)
		96	0	7.6	-	1990;8/92-12/99	(b)
Perchlorate	ug/L	7	7	4	0	1997-2003	(a)
Phosphate	mg/L	9	9	0.06	0.02	1995-2003	(a)
Potassium	mg/L	9	0	1.3	0.4	1995-2003	(a)
Silica	mg/L	9	0	5.8	2	1995-2003	(a)
Sodium	mg/L	9	0	9.9	1.3	1995-2003	(a)
Boron	ug/L	1	0	94		2003	(a)
Bromide	mg/L	26	15	0.020	0.008	1990;8/92-12/99	(b)
Total Organic Carbon	mg/L	88		4.4	2.3	1990;8/92-12/99	(b)
Microbiological							
Total Coliform	MPN/100ml	48	4	489	-	3/03-3/04	(c)
	MPN/100ml	413	87	23	-	5/94-2/03	(d)
Fecal Coliform	MPN/100ml	48	21	1	-	3/03-3/04	(c)
	MPN/100ml	190	114	1	-	2/99-2/03	(d)
Giardia	cysts/L	39	37	0.11	0.28	1/01-8/03	(e)
Cryptosporidium	oocysts/L	39	37	0.11	0.29	1/01-8/03	(e)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) Monthly averages from SFPUC excel file
(c) SFPUC data file- Calaveras Reservoir only
(d) SFPUC data file- SVWTP influent (Calaveras & San Antonio Reservoir sources)
(e) SFPUC web page
(f) Median values reported for pH, turbidity, total coliform, and fecal coliform

2.3.6 Hetch Hetchy Treated Water

The Alameda East monitoring station was recommended as the most appropriate and representative station to characterize the treated water derived directly from the Hetch Hetchy Reservoir (without storage in a local reservoir). The Alameda East monitoring station is the compliance point for SFPUC monitoring of their treated Hetch Hetchy water directly entering the regional system. Data for the Alameda East station was supplied by SFPUC. A summary of the data that were available from SFPUC for the Alameda East station is presented in Table 2.10.

Table 2.10 Data Summary for Alameda East Station (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Aluminum	ug/L	6	1	61.5	10.4	1995-2000	(a)
Antimony	ug/L	6	6	5.2	0.4	1995-2000	(a)
Arsenic	ug/L	6	6	2	0.6	1995-2000	(a)
Barium	ug/L	6	3	21	39	1995-2000	(a)
Berylium	ug/L	6	6	1	0	1995-2000	(a)
Cadmium	ug/L	6	6	1	0	1995-2000	(a)
Chromium	ug/L	6	6	3.3	3.3	1995-2000	(a)
Fluoride	mg/L	6	6	0.1	0.02	1995-2000	(a)
Lead	ug/L	6	6	2.2	1.5	1995-2000	(a)
Mercury	ug/L	6	6	0.7	0.3	1995-2000	(a)
Nickel	ug/L	6	6	4.2	2.9	1995-2000	(a)
Nitrate (as NO_3)	mg/L	6	6	0.6	0.7	1995-2000	(a)
Nitrite (as N)	mg/L	6	6	0.1	0.1	1995-2000	(a)
Selenium	ug/L	6	6	5	0	1995-2000	(a)
Thalium	ug/L	6	6	1	0	1995-2000	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	3	3	1.3	1.44	1997-2000	(a)
Total Trihalomethanes	ug/L	4	0	37.8	2.22	1995-2000	(a)
	ug/L	93		36.6	5.71	8/99-11/03	(f)
Contaminants with Secondary MCLs							
Chloride	mg/L	6	2	3.3	0.5	1995-2000	(a)
	mg/L	79		3.7	1.0	1992-1999	(e)
Color	units	4	0	7.3	0.5	1995-2000	(a)
Copper	ug/L	6	3	10	19	1995-2000	(a)
Foaming Agent (MBAS)	mg/L	4	4	0.3	0.3	1997-2000	(a)
Iron	ug/L	6	1	37	37	1995-2000	(a)
Manganese	ug/L	6	5	7.3	11	1995-2000	(a)
Odor Threshold	TON	4	1	1.3	0.5	1997-2000	(a)
Silver	ug/L	6	6	2.5	3.7	1995-2000	(a)
Specific Conductance	uS/cm	4	0	37	2.3	1997-2000	(a)
	uS/cm	80		43.4	8.6	1992-1999	(e)
Sulfate	mg/L	6	0	1.2	0.3	1995-2000	(a)
Total Dissolved Solids	mg/L	6	1	24.2	5.3	1995-2000	(a)
	mg/L	80		27.7	5.5	1992-1999	(e)
Turbidity	NTU	6	1	0.4	-	1995-2000	(a)
	NTU	74		0.35	-	1992-1999	(e)
Zinc	ug/L	6	6	12.7	18.3	1995-2000	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	6	1	12.8	0.98	1995-2000	(a)
	mg/L	60		92.1	8.9	1992-1999	(e)
Calcium	mg/L	6	1	3.6	0.53	1995-2000	(a)
Hardness (as $CaCO_3$)	mg/L	6	1	10.5	1.22	1995-2000	(a)
	mg/L	67		14.0	11.1	1992-1999	(e)
Magnesium	mg/L	6	4	0.4	0.16	1995-2000	(a)
pH	units	6	0	9.6	-	1995-2000	(a)
	units	80		9.60	-	1992-1999	(e)
Phosphate	mg/L	6	6	0.049	0.02	1995-2000	(a)
Potassium	mg/L	6	3	0.4	0.15	1995-2000	(a)
Silica	mg/L	6	0	3.9	0.64	1995-2000	(a)
Sodium	mg/L	6	4	3	0.04	1995-2000	(a)
Bromide	mg/L	35	34	0.034	0.031	1992-1999	(e)
Total Organic Carbon	mg/L	51		1.362	0.684	1995-1999	(e)
Microbiological							
Total Coliform	MPN/100ml	3285	3274	2	-	1995-2003	(b)
E. Coli	CFU/100ml	11	11	2	-	1995-2003	(d)
Giardia	cysts/L	166	161	0.04	0.04	1/01-3/04	(c)
Cryptosporidium	oocysts/L	166	160	0.04	0.04	1/01-3/04	(c)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) Correspondence with SFPUC; individual values are not available, only positive values reported
(c) SFPUC website College Hill Outlet and University Mound Reservoir locations
(d) Correspondence with SFPUC; E. coli is only analyzed when total coliform results are positive
(e) Monthly averages from SFPUC excel file
(f) SFPUC excel file
(g) Median values reported for pH, turbidity, total coliform, and E, Coli

2.3.7 Bay Area Reservoir Treated Water

The Sunol Valley Water Treatment Plant (SVWTP) monitoring station was recommended as the most appropriate and representative station to characterize the treated water derived from local reservoirs. As noted previously, the water stored in local reservoirs is a combination of local water and Hetch Hetchy Reservoir water that has been stored locally. Data for the SVWTP monitoring station was supplied by SFPUC. A summary of the data that were available from SFPUC for the SVWTP monitoring station is presented in Table 2.11. Based on hydrology simulations from Environmental Defense, it is estimated that on average approximately 75% source water for the SVWTP is currently derived from local sources and 25% is Hetch Hetchy water that is stored in a local reservoir prior to treatment (refer to Table 1.2).

2.3.8 Summary of Data Available for Water Quality Evaluation

In sections 2.3.1 through 2.3.6, the available data were presented for each of the relevant source waters to characterize the water quality of the components of raw and treated water within the Hetch Hetchy water supply system. Data summaries presented the total number of observations, the number of observations below detectable limits, the average and standard deviation of the observed concentrations, the date range from which the data were summarized, and the source of the available data.

To facilitate a comparison of the relative water qualities of the various raw and treated waters, a summary table presenting average concentrations of the constituents evaluated in this water quality evaluation is presented in Tables 2.12a and 2.12b. The average values in Tables 2.12.a and 2.12b were computed from the data presented previously in Tables 2.3 through 2.11.

In reviewing Tables 2.3 through 2.11 it is clear that many of the constituents had observations that were reported below detectable limits. Because all observations below detectable limits were assumed to be present at the detection limit for the purposes of the data summaries presented herein, it is important to be able to identify the average concentrations in Tables 2.12a and 2.12.b that are primarily a function of the analytical detection limit. For this purpose, cases in which 90% or greater of the observations were reported below detectable limits are bolded and shaded in Tables 2.12a and 2.12b.

As illustrated in Tables 2.12a and 2.12b many of the monitored constituents were below detectable limits at least 90% of the time. For example, all of the organic chemicals except MTBE, total THMs, and 2,4-D met this criteria. Similarly, radionuclides analyzed in the raw waters also met this criteria (treated waters were not analyzed for radionuclides). To facilitate the comparison between the various water sources, it was assumed for the purpose of this evaluation, that in cases where at least 90% of the observed data for a particular constituent were below detectable limits for all water sources, that the concentrations of that constituent in all waters were effectively equivalent. Employing this assumption effectively focuses the water quality evaluation on constituents that were detected (detectable constituents) in the various raw and treated waters.

Table 2.11 Data Summary for Sunol Valley Water Treatment Plant (Source SFPUC)

	Units	# Samples	# <MDL	Average	Standard Deviation	Date Range	Data Source
Inorganic Chemicals							
Aluminum	ug/L	6	1	27	15	1995-2000	(a)
Antimony	ug/L	6	6	5	0	1995-2000	(a)
Arsenic	ug/L	6	4	2	0.6	1995-2000	(a)
Barium	ug/L	6	1	67	19	1995-2000	(a)
Berylium	ug/L	6	6	1	0	1995-2000	(a)
Cadmium	ug/L	6	6	1	0	1995-2000	(a)
Chromium	ug/L	6	6	3	3	1995-2000	(a)
Fluoride	mg/L	6	2	0.1	0	1995-2000	(a)
Lead	ug/L	6	4	2.8	1.2	1995-2000	(a)
Mercury	ug/L	6	6	0.67	0.26	1995-2000	(a)
Nickel	ug/L	6	6	3.2	3.7	1995-2000	(a)
Nitrate (as NO_3)	mg/L	6	1	1.4	0.5	1995-2000	(a)
Nitrite (as N)	mg/L	6	6	0.11	0.14	1995-2000	(a)
Selenium	ug/L	6	6	5	0	1995-2000	(a)
Thalium	ug/L	6	6	1	0	1995-2000	(a)
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	3	3	1.3	1.4	1997-2000	(a)
Total Trihalomethanes	ug/L	4	0	32	5.5	1997-2000	(a)
Contaminants with Secondary MCLs							
Chloride	mg/L	6	0	14	7	1995-2000	(a)
		79	0	19	21	1992-1999	(b)
Color	units	4	4	3	2	1997-2000	(a)
Copper	ug/L	6	2	20	25	1995-2000	(a)
Foaming Agent (MBAS)	mg/L	4	4	0.3	0.3	1997-2000	(a)
Iron	ug/L	6	5	22	38	1995-2000	(a)
Manganese	ug/L	6	4	7.7	10.9	1995-2000	(a)
Odor Threshold	TON	4	1	1.3	0.5	1997-2000	(a)
Silver	ug/L	6	6	2.5	3.7	1995-2000	(a)
Specific Conductance	uS/cm	4	0	269	31	1997-2000	(a)
		79	0	299	83	1992-1999	(b)
Sulfate	mg/L	6	0	33	1.6	1995-2000	(a)
Total Dissolved Solids	mg/L	6	0	167	29	1995-2000	(a)
		79	0	191	53	1992-1999	(b)
Turbidity	NTU	6	0	0.06	-	1995-2000	(a)
		74	0	0.10	-	1992-1999	(b)
Zinc	ug/L	6	6	13	18	1995-2000	(a)
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	6	0	89	17	1995-2000	(a)
		66	0	95	16	1992-1999	(b)
Calcium	mg/L	6	0	22	5	1995-2000	(a)
Hardness (as $CaCO_3$)	mg/L	6	0	99	9	1995-2000	(a)
		66	0	101	14	1992-1999	(b)
Magnesium	mg/L	6	0	9.2	1.2	1995-2000	(a)
pH	units	6	0	8.1	-	1995-2000	(a)
		79	0	8.60	-	1992-1999	(b)
Phosphate	mg/L	6	5	0.05	0.02	1995-2000	(a)
Potassium	mg/L	6	0	1.43	0.33	1995-2000	(a)
Silica	mg/L	6	0	8.3	1.6	1995-2000	(a)
Sodium	mg/L	6	0	21	6.1	1995-2000	(a)
Bromide	mg/L	29	26	0.03	0.02	12/95-12/98	(b)
Total Organic Carbon	mg/L	47	0	2.54	0.87	1992-1999	(b)
Microbiological							
Total Coliform	MPN/100ml	3285	3281	2	-	1995-2003	(c)
E. Coli	CFU/100mL	4	4	2	-	1995-2003	(d)

Footnotes:
(a) SFPUC Sanitary Survey Reports
(b) Monthly averages from SFPUC excel file
(c) Correspondence with SFPUC; individual values are not available, only positive values reported
(d) Correspondence with SFPUC; E. coli is only analyzed when total coliform results are positive
(e) Median values reported for pH, turbidity, total coliform, and E. coli

A summary of the average concentrations of detectable constituents in raw source waters and treated waters in the SFPUC water supply system is presented in Table 2.13. This means that only constituents that were detected in at least one of the source waters are listed. However, for certain waters, these constituents were not detectable, thus, bolding and shading is used to differentiate between detectable constituents from those that were below detectable limits at least 90% of the time. The concentration values shown in Table 2.13 are employed in Sections 3 though 5 of this memorandum to characterize current and projected future water quality.

As shown in Table 2.13 all primary and secondary Maximum Contaminant Levels (MCLs) (Attachment 3) are met in the treated waters. The primary differences between Hetch Hetchy treated water (disinfected) and product water from the SVWTP (filtered and disinfected) may be summarized as follows:

- ◇ Hetch Hetchy water has extremely low total dissolved solids, specific conductance, and hardness;
- ◇ SVWTP water is lower in aluminum and iron; and
- ◇ Hetch Hetchy water is lower in barium, copper and alkalinity, and minerals (chloride, sulfate, calcium, magnesium, silica, and sodium).

Further inspection of Table 2.13 indicates that the raw Hetch Hetchy supply is of higher quality than any of the other available raw waters (Don Pedro, Delta, or Local water). Comparison of the concentrations of inorganic constituents in the raw waters indicates that aluminum, barium, and manganese are lower in the Hetch Hetchy raw water than in the other raw waters. Iron concentrations in the Hetch Hetchy raw water is similar to the Delta supply and lower than either Don Pedro or local waters, and chromium concentrations in the Hetch Hetchy raw water are similar to those in Don Pedro and local waters, and lower than Delta supply.

MTBE concentrations in the Hetch Hetchy raw water is similar to the local supply and lower than either Don Pedro or the Delta.

Table 2.12a Average Concentrations of Water Quality Evaluation Constituents for Raw and Treated Water Supplies

		Raw Waters				Treated Waters	
Inorganic Chemicals	Units	Hetch Hetchy Supply	Don Pedro Supply	Local Supply	Delta Supply	Hetch Hetchy (Alameda East)	Local Water (SVWTP Water)
Asbestos	MFL	0.2		0.2	15.7		
Aluminum	ug/L	70	112	94	164	62	27
Antimony	ug/L	5.1	5.2	5.1	3.2	5.2	5
Arsenic	ug/L	3.2	2	2	2.1	2	2
Barium	ug/L	5	26	68	110	21	67
Berylium	ug/L	1.0	1.0	1.0	1.0	1.0	1.0
Cadmium	ug/L	1	1	1	1	1	1
Chromium	ug/L	2.2	3.3	2.6	4.6	3.3	3.0
Cyanide	ug/L	0.1		0.1	20		
Fluoride	mg/L	0.09	0.09	0.1	0.10	0.1	0.1
Lead	ug/L	1.7	2.2	1.7	2.0	2.2	2.8
Mercury	ug/L	0.6	0.7	1.4	0.7	0.7	0.7
Nickel	ug/L	4.7	4.2	2.1	3.6	4.2	3.2
Nitrate (as NO_3)	mg/L	0.4	0.6	1.8	0.6	0.6	1.4
Nitrite (as N)	mg/L	0.06	0.11	0.40	0.11	0.10	0.11
Selenium	ug/L	5.0	5.0	3.9	1.3	5.0	5.0
Thalium	ug/L	1.0	1.0	1.9	1.0	1.0	1.0
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	0.5	2.8	0.5	1.1	1.3	1.3
Total Trihalomethanes	ug/L	0.5	0.5	0.5	451	36.6	32
2,4-D	ug/L	0.1	2		0.15		
Aldrin	ug/L	0.06	0.02	0.07	0.03		
Benzo(a)pyrene	ug/L	0.05	0.10	0.10	0.10		
Butachlor	ug/L	0.18	1.00	0.20	0.38		
Carbaryl	ug/L	3.2	5.0	3.8	2.0		
Dicamba	ug/L	0.65		0.90	0.09		
Dieldrin	ug/L	0.02	0.02	0.02	0.02		
Dinoseb	ug/L	0.92	1.00	1.30	0.13		
Diquat	ug/L	1.84	1.25	2.6	4		
Diuron	ug/L		0.1	1	0.25		
Glyphosate	ug/L	6	20	6	94.6		
3-Hydroxycarbofuran	ug/L	2.6	10	2.6	2.0		
Methomyl	ug/L	1.4	5	1.6	2.0		
Metolachlor	ug/L	0.19	1.0	0.3	0.29		
Metribuzin	ug/L	0.19	0.1	0.3	0.5		
Oxamyl	ug/L	9.2	5.0	12.8	2.0		
Propachlor	ug/L	0.23	1.0	0.3	0.5		
Radionuclides							
Total Alpha Particle	pCi/L	1		1			
Total Beta Particle	pCi/L	4		4			
Strontium-90	pCi/L	2		2			
Tritium	pCi/L	778		572			
Uranium	pCi/L	2		2			
Radon-222	pCi/L	100		100			

Notes:

1. Shaded values indicate that greater than 90% of the observed values were reported to be below detectable limits.
2. Blank spaces in this table indicate that no monitoring data were available.
3. Total THM data for Delta supply represents TTHM formation potential, THM data for other raw source waters represent measured total THM concentrations.

Table 2.12b Average Concentrations of Water Quality Evaluation Constituents for Raw and Treated Water Supplies (cont'd)

		Raw Waters				Treated Waters	
Inorganic Chemicals	**Units**	Hetch Hetchy Supply	Don Pedro Supply	Local Supply	Delta Supply	Hetch Hetchy (Alameda East)	Local Water (SVWTP Water)
Contaminants with Secondary MCLs							
Chloride	mg/L	**2.8**	**3.0**	7.0	52.3	3.6	19.0
Color	units	8.9	22.8	25.4	40.1	7.3	**3.0**
Copper	ug/L	6.8	10.6	8.6	4.0	10.4	20.0
Foaming Agent (MBAS)	mg/L	**0.5**		0.5		**0.3**	**0.3**
Iron	ug/L	39	121	76	41	37	22
Manganese	ug/L	5.3	12.7	10.7	31.4	7.3	7.7
Odor Threshold	TON	**1.0**		1.0		1.3	1.3
Silver	ug/L	**1.7**	**2.5**	**2.0**	**2.1**	**2.5**	**2.5**
Specific Conductance	uS/cm	12	40	239	374	43	297
Sulfate	mg/L	0.6	1.9	19.8	30.6	1.2	33.0
Total Dissolved Solids	mg/L	11	31	148	216	27	189
Turbidity	NTU	0.5	2.5	10.3	12.7	0.5	0.1
Zinc	ug/L	10.2	13.2	**9.0**	**8.0**	**12.7**	**13.0**
Minerals and General Parameters							
Alkalinity (as $CaCO_3$)	mg/L	4.8	18.0	96.8	66.1	84.9	94.7
Calcium	mg/L	1.3	3.8	27.2	15.8	3.6	22.0
Hardness (as $CaCO_3$)	mg/L	4	17	104	84	14	100
Magnesium	mg/L	**0.4**	1.9	9.5	10.5	0.4	9.2
pH	units	7.1	8.4	7.7	7.4	9.5	8.5
Perchlorate	ug/L	**3.5**		**4.0**			
Phosphate	mg/L	**0.06**	0.05	**0.06**	0.13	**0.05**	0.05
Potassium	mg/L	0.4	0.5	1.3	1.5	0.4	1.4
Silica	mg/L	3.8	7.0	5.8	14.5	3.9	8.3
Sodium	mg/L	**3.0**	**3.0**	9.9	39.4	3.0	21.0
Boron	ug/L	8.5		94	160		
Bromide	mg/L			0.020	159	**0.034**	**25**
Total Organic Carbon	mg/L	1.4	**0.5**	4.4	3.8	1.36	2.5
Microbiological							
Total Coliform [1,2]	MPN/100ml	7	13	30	210	**2**	**2**
Fecal Coliform [1,2]	MPN/100ml	2	2	1	55		
E. coli	CFU/100mL				13	**2**	**2**
Giardia	cysts/L	0.04	**0.10**	**0.11**	**0.09**	**0.04**	
Cryptosporidium	oocysts/L	**0.04**	0.11	**0.11**	**0.16**	**0.036**	

1 Hetchy Hetchy Reservoir coliform data was used to calculate average value for Hetch Hetchy supply
2 Don Pedro Reservoir SFPUC coliform data was used to calculate average value for Don Pedro supply
3. Median values reported for bacteriological data

Total THM data in Table 2.13 for the Delta supply represents TTHM formation potential, whereas THM data for other raw source waters represent measured total THM concentrations. Total trihalomethane concentrations in the Hetch Hetchy, Don Pedro and local waters are similar. Total trihalomethane formation potential is higher in the Delta water than in other raw source waters.

Table 2.13 Average Concentrations of Detectable Water Quality Evaluation Constituents for Raw and Treated Water Supplies

Contaminant	Units	Hetch Hetchy Supply	Don Pedro Supply	Local Supply	Delta Supply	Hetch Hetchy	Local Water
Inorganic Chemicals							
Aluminum	ug/L	70	112	94	164	62	27
Barium	ug/L	**5**	26	68	110	21	67
Chromium	ug/L	**2.2**	**3.3**	**2.6**	4.6	**3.3**	**3.0**
Copper	ug/L	6.8	10.6	8.6	4.0	10.4	20.0
Iron	ug/L	39	121	76	41	37	22
Manganese	ug/L	5.3	12.7	10.7	31.4	7.3	7.7
Zinc	ug/L	10.2	13.2	**9.0**	**8.0**	**12.7**	**13.0**
Organic Chemicals							
Methl Tertiary Butyl Ether	ug/L	**0.5**	2.8	**0.5**	1.1	**1.3**	**1.3**
Total Trihalomethanes	ug/L	**0.5**	**0.5**	**0.5**	451	36.6	32
Minerals and General Parameters							
Nitrate (as NO_3)	mg/L	**0.4**	**0.6**	1.8	0.6	**0.6**	1.4
Nitrite (as N)	mg/L	**0.06**	**0.11**	0.40	**0.11**	**0.10**	**0.11**
Chloride	mg/L	**2.8**	**3.0**	7.0	52.3	3.6	19.0
Sulfate	mg/L	0.6	1.9	19.8	30.6	1.2	33.0
Calcium	mg/L	1.3	3.8	27.2	15.8	3.6	22.0
Hardness (as $CaCO_3$)	mg/L	4	17	104	84	14	100
Magnesium	mg/L	**0.4**	1.9	9.5	10.5	0.4	9.2
Phosphate	mg/L	**0.06**	0.05	**0.06**	0.13	**0.05**	0.05
Potassium	mg/L	0.4	0.5	1.3	1.5	0.4	1.4
Silica	mg/L	3.8	7.0	5.8	14.5	3.9	8.3
Sodium	mg/L	**3.0**	**3.0**	9.9	39.4	3.0	21.0
Total Dissolved Solids	mg/L	11	31	148	216	27	189
Turbidity	NTU	0.5	2.5	10.3	12.7	0.5	0.1
Total Organic Carbon	mg/L	1.4	**0.5**	4.4	3.8	1.36	2.5
Specific Conductance	uS/cm	11.5	40.3	239.3	373.8	43.1	297.4
Alkalinity (as $CaCO_3$)	mg/L	4.8	18.0	96.8	66.1	84.9	94.7
Color	units	8.9	22.8	25.4	40.1	7.3	**3.0**
pH	units	7.1	8.4	7.7	7.4	9.5	8.5
Microbiological							
Total Coliform	MPN/100ml	7	13	30	210	**2**	**2**
Fecal Coliform	MPN/100ml	2	2	1	55		

Note: Total THM data for Delta supply represents TTHM formation potential, THM data for other raw source waters represent measured total THM concentrations.

Minerals and general parameter concentrations are also lower in the Hetch Hetchy raw water than in other raw waters. All minerals and general parameters in the Hetch Hetchy raw water are lower than in the Delta raw water with the possible exception of nitrate and nitrite. Similarly, all minerals and general parameters in the Hetch Hetchy raw water are lower than in the local water with the possible exceptions of phosphate and silica which appear to be present in similar concentrations. Most minerals and general parameters are present in Don Pedro water in similar concentrations to those in Hetch Hetchy water, except sulfate, calcium, and magnesium which are present in higher concentrations. The hardness, alkalinity, specific conductance, total dissolved solids, and color is also higher in Don Pedro water than the Hetch Hetchy raw water. The average total organic carbon concentration in the Don Pedro water is lower than other waters, but is based on a single sample.

The total coliform and fecal coliform levels are lower in the Hetch Hetchy raw water than in other raw waters, although the fecal coliform levels in the Don Pedro and local water is also very low. Note that a direct comparison between the raw waters and drinking water MCLs was not carried out because all of the raw waters will be treated (filtered and/or disinfected) prior to delivery.

3.0 Current and Projected Future Finished Water Quality With Hetch Hetchy Reservoir

3.1 Current Finished Water Quality

As noted previously, SFPUC currently delivers water to its customers that is derived primarily from three sources: Hetch Hetchy Reservoir (without local storage), Hetch Hetchy Reservoir after storage in local reservoir, and local water after storage in a local reservoir. Water quality summaries for treated (disinfected) Hetch Hetchy water and treated local water were presented in Tables 2.10 and 2.11, respectively. The average concentrations of detected constituents for these treated waters are compared in Table 2.13.

The specific combination of the source waters that SFPUC delivers at any point in time varies on both short (monthly) and longer (annual) time frames. Environmental Defense provided TREWSSIM results for this water quality evaluation describing the volume of each type of water that is predicted to be delivered by SFPUC for a range of hydrologic conditions. The hydrologic conditions supplied by Environmental Defense for this evaluation include: 1) an average of hydrologic year (for hydrology from 1922 to 1994), 2) average of hydrologic years during drought conditions (for hydrology 1987 to 1992), 3) maximum use of upstream supply (based on 1922-1994 monthly hydrology), and 4) maximum use of local supply (based on 1922-1994 monthly hydrology).

The predicted volumes of water delivered by SFPUC under current demand based on TREWSSIM modeling and the hydrology conditions described above, are presented in Table 3.1. The maximum upstream and maximum local per month total water supply delivered are based on 1922 – 1994 February hydrology estimates. Winter months have lower water supply demand, therefore the estimated volume of delivered water on a monthly basis is less than one twelfth the annual total water delivered.

Table 3.1. Volume of Water Assumed to be Delivered by SFPUC under Current Demand

(Units are thousand acre-feet)

Source	Annual Average (per year)	Drought Average (per year)	Maximum Upstream Usage [1] (per month)	Maximum Local Usage[2] (per month)
Local Water From Local Storage	34	15	0	12
Tuolumne Water Via Local Storage	12	8	0	2
Tuolumne River Water From Upstream	242	240	18	4
Don Pedro Water Via Local Storage	0	0	0	0
Don Pedro Direct Diversion	0	0	0	0
Delta Water Via Local Storage	0	0	0	0
Delta Direct Diversion	0	0	0	0
Total	288	262	18	18

Data Source: Environmental Defense

1. Based on February 1994 hydrology
2. Based on February 1983 hydrology

Based on the assumed range of source water mixtures shown in Table 3.1 and the estimated concentrations of detected constituents in finished water (Table 2.13), a summary of predicted

SFPUC delivered water quality for current demand was computed (i.e. weighted averages). A summary of those predicted values is presented in Table 3.2. Note: the predicted water quality shown in Table 3.2 is based on available data as described previously, and that constituents that were reported to be principally below detectable limits in all waters are not shown.

Table 3.2 Predicted Water Quality of Combined Treated Water for Existing Demand

Constituent	Units	Annual Average	Drought Average	Maximum Upstream	Maximum Local
Inorganic Chemicals					
Aluminum	ug/L	56	59	62	35
Barium	ug/L	28	25	21	57
Chromium	ug/L	3.3	3.3	3.3	3.1
Copper	ug/L	12	11	10	18
Iron	ug/L	34	36	37	25
Manganese	ug/L	7	7	7	8
Zinc	ug/L	13	13	13	13
Organic Chemicals					
Methl Tertiary Butyl Ether	ug/L	1.2	1.3	1.3	0.9
Total Trihalomethanes [1]	ug/L	37	37	38	33
Minerals and General Parameters					
Nitrate (as NO_3)	mg/L	0.7	0.7	0.6	1.2
Nitrite (as N)	mg/L	0.1	0.1	0.1	0.1
Chloride	mg/L	5.8	4.6	3.3	15.5
Sulfate	mg/L	6.3	3.9	1.2	25.9
Calcium	mg/L	6.5	5.2	3.6	17.9
Hardness (as $CaCO_3$)	mg/L	25	18	11	80
Magnesium	mg/L	1.8	1.1	0.4	7.3
Phosphate	mg/L	0.05	0.05	0.05	0.05
Potassium	mg/L	0.6	0.5	0.4	1.2
Silica	mg/L	4.6	4.3	3.9	7.3
Sodium	mg/L	5.9	4.5	3.0	17.0
Total Dissolved Solids	mg/L	51	38	24	153
Turbidity	NTU	0.4	0.4	0.4	0.2
Total Organic Carbon	mg/L	1.5	1.5	1.4	2.2
Specific Conductance	uS/cm	79	59	37	239
Alkalinity (as $CaCO_3$)	mg/L	26	20	13	76
Color	units	7	7	7	4
Microbiological					
Total Coliform	MPN/100ml	2	2	2	2

1. SFPUC switched to choramine disinfection in 2004, so these values may not be representative of future TTHM concentrations, which are expected to be lower as a result of the switch.

3.2 Projected Finished Future Water Quality with Hetch Hetchy Reservoir

The SFPUC predicts that there will be a demand of 339 TAF in 2030 (San Francisco Public Utilities Commission and Bay Area Water Users Association 2000). Provided that the Hetch Hetchy Reservoir remains part of the water supply system, it is likely that SFPUC will (under normal operating conditions) continue to deliver water from the same three sources as currently utilized (refer to section 3.1) .

For the purposes of this planning level water quality evaluation, it is assumed that the water quality of the Hetch Hetchy finished water will not change appreciably in the foreseeable future. This assumption is not to indicate that normal variation in water quality does not occur, but rather that operational changes or source water fluctuations will not significantly impact the Hetch Hetchy source water quality.

Similar to the analysis presented in Section 3.1, Environmental Defense also supplied TREWSSIM results describing the volume of each type of water predicted to be delivered by SFPUC for a range of hydrologic conditions under 2030 demand (339 TAF). The hydrologic conditions investigated by Environmental Defense are the same as those described in section 3.1. The volume of water predicted by TREWSSIM to be delivered by SFPUC under 2030 demand and the hydrology assumptions described in section 3.1, are presented in Table 3.3.

Table 3.3. Volume of Water Assumed to be Delivered by SFPUC under 2030 Demand

(Units are thousand acre-feet)

Source	Annual Average (per year)	Drought Average (per year)	Maximum Upstream Usage [1] (per month)	Maximum Local Usage[2] (per month)
Local Water From Local Storage	39	62	0	13
Tuolumne River Water Via Local Storage	60	125	0	10
Tuolumne River Water From Upstream	240	152	23	0
Don Pedro Water Via Local Storage	0	0	0	0
Don Pedro Direct Diversion	0	0	0	0
Delta Water Via Local Storage	0	0	0	0
Delta Direct Diversion	0	0	0	0
Total	339	339	23	23

Data Source: Environmental Defense

1. Based on February 1994 hydrology
2. Based on February 1983 hydrology

Based on TREWSSIM results, a substantial amount of Hetch Hetchy (Tuolumne River) water (60 TAF per year on average year and 125 TAF per year during drought years) will need to be stored locally (and subsequently treated) prior to delivery under 2030 demand conditions. To estimate (2030) water quality of the future blended SFPUC supply, it is necessary to the project the future water quality of the Hetch Hetchy water that will be stored and subsequently treated.

Given the technical complexities surrounding water quality of water residing in a reservoir, it is difficult to predict how the product water from SVWTP will change with the increased volume of Hetch Hetchy water to be stored locally prior to treatment. There are three feasible outcomes for each constituent of interest from storing additional Hetch Hetchy water locally: 1) The product water quality from the SVWTP will remain constant; 2) The SVWTP product water quality will vary proportionally to the amount of Hetch Hetchy water stored locally; and 3) The SVWTP product water quality will vary somewhat, but less than proportionally to the amount of Hetch Hetchy water stored locally.

Based on the assumed range of source water mixtures shown in Table 3.3 and the estimated concentrations of detected constituents in finished water (Table 2.13), a summaries of predicted

SFPUC delivered water quality for future (2030) demand are presented in Tables 3.4 and 3.5. Table 3.4 is based on the assumption that product water quality from the SVWTP remains constant even with additional Hetch Hetchy water stored locally, and Table 3.5 is based on the assumption that SVWTP product water quality increases proportionally to the amount of Hetch Hetchy water stored locally. The predicted water quality from the third outcome listed above will be between those shown in Tables 3.4 and 3.5.

Table 3.4. Predicted Water Quality of Combined Treated Water for Future (2030) Demand Assuming that SVWTP Product water Quality Remains Constant

Inorganic Chemicals	Units	Annual Average	Drought Average	Maximum Upstream	Maximum Local
Aluminum	ug/L	51	42	62	27
Barium	ug/L	34	46	21	67
Chromium	ug/L	3.2	3.1	3.3	3.0
Copper	ug/L	13	16	10	20
Iron	ug/L	32	29	37	22
Manganese	ug/L	7	8	7	8
Zinc	ug/L	13	13	13	13
Organic Chemicals					
Methl Tertiary Butyl Ether	ug/L	1.2	1.0	1.3	0.8
Total Trihalomethanes [1]	ug/L	35	34	37	32
Minerals and General Parameters					
Nitrate (as NO_3)	mg/L	0.8	1.0	0.6	1.4
Nitrite (as N)	mg/L	0.1	0.1	0.1	0.1
Chloride	mg/L	8.1	12.1	3.6	19.0
Sulfate	mg/L	10.5	18.7	1.2	33.0
Calcium	mg/L	9.0	13.7	3.6	22.0
Hardness (as $CaCO_3$)	mg/L	39	62	14	100
Magnesium	mg/L	3.0	5.3	0.4	9.2
Phosphate	mg/L	0.05	0.05	0.05	0.05
Potassium	mg/L	0.7	1.0	0.4	1.4
Silica	mg/L	5.2	6.3	3.9	8.3
Sodium	mg/L	8.2	12.9	3.0	21.0
Total Dissolved Solids	mg/L	75	117	27	189
Turbidity	NTU	0.4	0.3	0.5	0.1
Total Organic Carbon (TOC)	mg/L	1.7	2.0	1.4	2.5
Specific Conductance	uS/cm	117	183	43	297
Alkalinity (as $CaCO_3$)	mg/L	88	90	85	95
Color	units	6.0	4.9	7.3	3.0
Microbiological					
Total Coliform	MPN/100ml	2	2	2	2

1. SFPUC switched to chloramine disinfection in 2004, so these values may not be representative of future TTHM concentrations, which are expected to be lower as a result of the switch

Table 3.5. Predicted Water Quality of Combined Treated Water for Future (2030) Demand Assuming that SVWTP Product water Quality Changes Proportionally With Water Quality of Stored Water

Inorganic Chemicals	Units	Annual Average	Drought Average	Maximum Upstream	Maximum Local
Aluminum	ug/L	56	53	62	35
Barium	ug/L	28	32	21	56
Chromium	ug/L	3.3	3.2	3.3	3.1
Copper	ug/L	12	13	10	18
Iron	ug/L	35	33	37	26
Manganese	ug/L	7	7	7	8
Zinc	ug/L	13	13	13	13
Organic Chemicals					
Methl Tertiary Butyl Ether	ug/L	1.2	1.2	1.3	0.9
Total Trihalomethanes	ug/L	36	35	37	33
Minerals and General Parameters					
Nitrate (as NO_3)	mg/L	0.7	0.8	0.6	1.2
Nitrite (as N)	mg/L	0.1	0.1	0.1	0.1
Chloride	mg/L	6.0	7.4	3.6	15.2
Sulfate	mg/L	6.1	9.0	1.2	25.2
Calcium	mg/L	6.4	8.1	3.6	17.5
Hardness (as $CaCO_3$)	mg/L	27	35	14	79
Magnesium	mg/L	1.7	2.6	0.4	7.0
Phosphate	mg/L	0.05	0.05	0.05	0.05
Potassium	mg/L	0.6	0.7	0.4	1.2
Silica	mg/L	4.6	5.0	3.9	7.2
Sodium	mg/L	5.8	7.4	3.0	16.6
Total Dissolved Solids	mg/L	52	67	27	149
Turbidity	NTU	0.4	0.4	0.5	0.2
Total Organic Carbon	mg/L	1.5	1.6	1.4	2.2
Specific Conductance	uS/cm	82	105	43	235
Alkalinity (as CO_3)	mg/L	86	87	85	92
Color	units	6.6	6.2	7.3	4.1
Microbiological					
Total Coliform	MPN/100ml	2	2	2	2
Fecal Coliform	MPN/100ml				

Note: SFPUC switched to chloramine disinfection in 2004, so these values may not be representative of future TTHM concentrations, which are expected to be lower as a result of the switch.

Comparison of the range of projected water qualities under 2030 demand (Tables 3.4 and 3.5) with the estimated water quality of treated water for existing demand (Table 3.2) indicates that in all cases the delivered water is projected to be of very high quality relative to state and federal MCLs. Further, given that Hetch Hetchy water and SVWTP water is blended prior to distribution, very few differences exist between the predicted blended water qualities of current and future delivered water, especially given the variability that occurs with hydrologic conditions.

4.0 Alternative Operational Strategies to Hetch Hetchy Reservoir and Projected Raw Water Quality

If the Hetch Hetchy Reservoir is not part of the SFPUC water supply system in the future, there will be several possible alternative water supply strategies available for operating the water supply system. Each of those alternative water supply strategies will have an associated water quality, based on the mix of raw waters comprising the treated and delivered water. For this water quality evaluation, three alternative water supply strategies were investigated, based on information supplied by Environmental Defense. Alternative strategies for operating the SFPUC water system without the Hetch Hetchy Reservoir can be categorized as combinations of the following components:

- ◇ Delivery and/or storage of water from Don Pedro Reservoir,
- ◇ Delivery and/or storage of water from the San Joaquin Delta, and
- ◇ Increased use of local storage.

Specifically, the three alternatives investigated are as follows:

1. Future without Hetch Hetchy Reservoir maximizing Don Pedro diversion,
2. Future without Hetch Hetchy Reservoir maximizing Delta diversion, and
3. Future without Hetch Hetchy Reservoir using Don Pedro diversion and an expanded Calaveras Reservoir.

For each of the three future alternatives investigated without Hetch Hetchy Reservoir, it is assumed for the purposes of this water quality evaluation that all water delivered to SFPUC customers will be treated by filtration and disinfection.

In the following sections, raw water qualities (i.e. prior to filtration and disinfection) are projected for the three alternative operations of the Hetch Hetchy system described above, based on the available data for current raw waters. It is assumed that for each of the available raw water supplies (Hetch Hetchy (represents Tuolumne River water in this section), Don Pedro, Delta, and local water), the water quality associated with the current supply is a reasonable and representative proxy for the future supply.

Note that the raw water qualities presented in this section cannot be compared directly to the finished water qualities presented in Section 3, because it is assumed that under these alternatives all water will be filtered and disinfected prior to distribution. The relative water qualities of the raw source waters was presented previously in Table 2.13.

Also note that estimated concentrations of total trihalomethanes (TTHMS) are not presented in this section, because consistent data for TTHMS were not available for all raw source waters (THM data for the Delta supply were for TTHM formation potential and for other supplies were measured concentrations. These two types of measurements cannot be combined in a manner consistent with other constituents). However, it should be clear that the TTHM formation potential of blended raw waters will vary with the proportion of Delta water making up that blend.

Similar to the water quality analysis presented in Section 3, Environmental Defense supplied hydrologic modeling results describing the volume of each type of water that is predicted to be delivered by SFPUC for the alternatives under a range of hydrologic conditions for 2030 demand (339 TAF). The hydrologic conditions investigated by Environmental Defense for the alternatives described herein are the same as those described in Section 3. Note that the maximum upstream and maximum local volumes are less than one twelfth the annual values because the monthly values are based on the hydrology of a winter month when water demand is lower.

4.1 Future Raw Water Without Hetch Hetchy Reservoir Maximizing Don Pedro Diversion

Under all restoration alternatives, the SFPUC's use of existing local supplies and diversions of natural Tuolumne River flow in the reach below Hetch Hetchy Valley would provide more than 60% of its deliveries. Under the "Maximize Don Pedro Diversion" alternative, SFPUC would divert water from Don Pedro Reservoir to the SFPUC aqueduct through a new intertie. In this alternative it is assumed that there would be no expansion of storage in the Bay Area. Thus 95% of the water that would be diverted from Don Pedro would flow directly to the Sunol Valley Water Treatment Plant, then to customers in the Bay Area (TREWSSIM).

The predicted volumes of water to be delivered by SFPUC are presented in Table 4.1 for the Maximize Don Pedro diversion water supply alternative strategy and 2030 demand. The predicted volumes are based on Environmental Defense hydrology modeling and the hydrology assumptions described in section 3.1.

Table 4.1. Volume of Water Projected to be Delivered by SFPUC under Maximize Don Pedro Alternative and 2030 Demand

(Units are thousand acre-feet)

Source	Annual Average (per year)	Drought Average (per year)	Maximum Upstream Usage[1] (per month)	Maximum Local Usage[2] (per month)
Local Water From Local Storage	35	30	0	10.9
Tuolumne River Water After Local Storage	17	14	0	3.2
Tuolumne River Water From Upstream	161	130	28.0	5.9
Don Pedro Water After Local Storage	6	5	0	1.1
Don Pedro Direct Diversion	121	161	0	0
Delta Water After Local Storage	0	0	0	0
Delta Direct Diversion	0	0	0	0
Total	339	339	28.0	21.2

Data Source: Environmental Defense

1. Based on February 1994 hydrology

2. Based on February 1983 hydrology

A summary of the projected raw water quality for the Maximize Don Pedro Alternative is presented in Table 4.2.

Table 4.2. Projected Raw Water Quality for Maximize Don Pedro Alternative

Inorganic Chemicals	Units	Annual Average	Drought Average	Maximum Upstream	Maximum Local
Aluminum	ug/L	88	93	70	84
Barium	ug/L	19	21	5	39
Chromium	ug/L	2.6	2.8	2.2	2.4
Copper	ug/L	8	9	7	8
Iron	ug/L	74	82	39	62
Manganese	ug/L	9	9	5	8
Zinc	ug/L	11	12	10	10
Organic Chemicals					
Methl Tertiary Butyl Ether	ug/L	1.4	1.6	0.5	0.6
Minerals and General Parameters					
Nitrate (as NO_3)	mg/L	0.6	0.6	0.4	1.1
Nitrite (as N)	mg/L	0.11	0.11	0.06	0.24
Chloride	mg/L	3.3	3.3	2.8	5.0
Sulfate	mg/L	3.1	2.9	0.6	10.6
Calcium	mg/L	4.9	4.8	1.3	14.8
Hardness (as $CaCO_3$)	mg/L	19	19	4	56
Magnesium	mg/L	1.9	1.9	0.4	5.2
Phosphate	mg/L	0.1	0.1	0.1	0.1
Potassium	mg/L	0.6	0.6	0.4	0.9
Silica	mg/L	5.2	5.6	3.8	5.0
Sodium	mg/L	3.7	3.6	3.0	6.6
Total Dissolved Solids	mg/L	32	33	11	82
Turbidity	NTU	2.3	2.3	0.5	5.7
Total Organic Carbon	mg/L	1.4	1.2	1.4	2.9
Specific Conductance	uS/cm	46	45	12	130
Alkalinity (as $CaCO_3$)	mg/L	19	19	5	53
Color	units	16	17	9	18
pH	units	7.7	7.8	7.1	7.5
Microbiological					
Total Coliform	MPN/100ml	12	12	7	19
Fecal Coliform	MPN/100ml	2	2	2	1

1. Microbiological data computed based on median values

4.2 Future Raw Water Without Hetch Hetchy Reservoir Maximizing Delta Diversion

As noted in Section 4.1, under all restoration alternatives, the SFPUC's use of existing local supplies and diversions of natural Tuolumne River flow in the reach below Hetch Hetchy Valley would provide more than 60% of its deliveries. Under the "Maximize Delta Diversion" alternative, SFPUC would divert water from the State Water Project's South Bay Aqueduct, its California Aqueduct, or the Central Valley Project's Delta Mendota Canal. About 90% of all Delta diversions would flow directly to the Sunol Valley Water Treatment Plant, then to customers in the Bay Area. The remaining 10% of Delta water would be diverted to local storage before treatment (TREWSSIM).

The predicted volumes of water to be delivered by SFPUC for the Maximize Delta Diversion water supply alternative, based on Environmental Defense hydrology modeling for 2030 demand are presented in Table 4.3.

Table 4.3. Volume of Water Projected to be Delivered by SFPUC under Maximize Delta Diversion Alternative and 2030 Demand

(Units are thousand acre-feet)

Source	Annual Average (per year)	Drought Average (per year)	Maximum Upstream Usage[1] (per month)	Maximum Local Usage[2] (per month)
Local Water From Local Storage	29	23	0	10.9
Tuolumne River Water After Local Storage	29	22	0	8.4
Tuolumne River Water From Upstream	153	129	28.0	0
Don Pedro Water After Local Storage	0	0	0	0
Don Pedro Direct Diversion	0	0	0	0
Delta Water After Local Storage	13	10	0	3.3
Delta Direct Diversion	115	156	0	0
Total	339	339	28.0	22.6

Data Source: Environmental Defense

1. Based on February 1994 hydrology

2. Based on February 1983 hydrology

A summary of the projected raw water quality for the Maximize Delta Diversion Alternative is presented in Table 4.4.

Table 4.4. Projected Raw Water Quality for Maximize Delta Diversion Alternative

Inorganic Chemicals	**Units**	Annual Average	Drought Average	Maximum Upstream	Maximum Local
Aluminum	ug/L	107	117	70	95
Barium	ug/L	50	61	5	51
Chromium	ug/L	3.1	3.4	2.2	2.7
Copper	ug/L	6	6	7	7
Iron	ug/L	43	43	39	57
Manganese	ug/L	16	18	5	12
Zinc	ug/L	9	9	10	9
Organic Chemicals					
Methl Tertiary Butyl Ether	ug/L	0.7	0.8	0.5	0.6
Minerals and General Parameters					
Nitrate (as NO_3)	mg/L	0.6	0.6	0.4	1.1
Nitrite (as N)	mg/L	0.11	0.11	0.06	0.23
Chloride	mg/L	21.8	27.3	2.8	12.1
Sulfate	mg/L	13.5	16.5	0.6	14.2
Calcium	mg/L	9.0	10.1	1.3	15.9
Hardness (as $CaCO_3$)	mg/L	43	50	4	64
Magnesium	mg/L	5.0	5.9	0.4	6.2
Phosphate	mg/L	0.1	0.1	0.1	0.1
Potassium	mg/L	0.9	1.0	0.4	1.0
Silica	mg/L	8.0	9.2	3.8	6.3
Sodium	mg/L	17.3	21.3	3.0	11.7
Total Dissolved Solids	mg/L	100	120	11	107
Turbidity	NTU	5.9	7.1	0.5	7.0
Total Organic Carbon (TOC)	mg/L	2.6	2.8	1.4	3.2
Specific Conductance	uS/cm	167	204	12	174
Alkalinity (as $CaCO_3$)	mg/L	36	41	5	58
Color	units	22	25	9	21
pH	units	7.3	7.3	7.1	7.5
Microbiological					
Total Coliform	MPN/100ml	85	108	7	48
Fecal Coliform	MPN/100ml	22	28	2	9

1. Microbiological data computed based on median values

4.3 Future Raw Water Without Hetch Hetchy Reservoir Using Don Pedro Diversion and an Expanded Calaveras Reservoir

As noted in Section 4.1, under all restoration alternatives, the SFPUC's use of existing local supplies and diversions of natural Tuolumne River flow in the reach below Hetch Hetchy Valley would provide more than 60% of its deliveries. Under the "Don Pedro Diversion / Expanded Calaveras" alternative SFPUC would divert water from Don Pedro Reservoir to the SFPUC aqueduct through a new intertie. About 90% of all such diversions would flow directly to the Sunol Valley Water Treatment Plant, then to customers in the Bay Area. The remaining 10% of the Don Pedro diversions would be diverted to local storage before treatment.

The predicted volumes of water to be delivered by SFPUC for the Don Pedro Diversion / Expanded Calaveras water supply alternative, based on Environmental Defense hydrology modeling for 2030 demand are presented in Table 4.5.

Table 4.5. Volume of Water Projected to be Delivered by SFPUC under Don Pedro Diversion / Expanded Calaveras Alternative and 2030 Demand

(Units are thousand acre-feet)

Source	Annual Average (per year)	Drought Average (per year)	Maximum Upstream Usage[1] (per month)	Maximum Local Usage[2] (per month)
Local Water From Local Storage	29	23	0	10.9
Tuolumne River Water After Local Storage	29	22	0	8.4
Tuolumne River Water From Upstream	153	129	28.0	0
Don Pedro Water After Local Storage	13	10	0	3.3
Don Pedro Direct Diversion	115	156	0	0
Delta Water After Local Storage	0	0	0	0
Delta Direct Diversion	0	0	0	0
Total	339	339	28.0	22.6

Data Source: Environmental Defense

1. Based on February 1994 hydrology

2. Based on February 1983 hydrology

A summary of the projected raw water quality for the Don Pedro Diversion / Expanded Calaveras Alternative is presented in Table 4.6.

Table 4.6. Projected Raw Water Quality for Don Pedro Diversion / Expanded Calaveras Alternative

Inorganic Chemicals	Units	Annual Average	Drought Average	Maximum Upstream	Maximum Local
Aluminum	ug/L	88	92	70	88
Barium	ug/L	18	19	5	38
Chromium	ug/L	2.6	2.7	2.2	2.5
Copper	ug/L	8	9	7	8
Iron	ug/L	73	82	39	69
Manganese	ug/L	9	9	5	9
Zinc	ug/L	11	12	10	10
Organic Chemicals					
Methl Tertiary Butyl Ether	ug/L	1.4	1.6	0.5	0.8
Minerals and General Parameters					
Nitrate (as NO_3)	mg/L	0.6	0.6	0.4	1.1
Nitrite (as N)	mg/L	0.11	0.11	0.06	0.23
Chloride	mg/L	3.2	3.2	2.8	4.8
Sulfate	mg/L	2.8	2.5	0.6	10.0
Calcium	mg/L	4.5	4.3	1.3	14.1
Hardness (as $CaCO_3$)	mg/L	17	17	4	54
Magnesium	mg/L	1.7	1.7	0.4	5.0
Phosphate	mg/L	0.1	0.1	0.1	0.1
Potassium	mg/L	0.5	0.5	0.4	0.9
Silica	mg/L	5.2	5.5	3.8	5.2
Sodium	mg/L	3.6	3.5	3.0	6.3
Total Dissolved Solids	mg/L	30	30	11	79
Turbidity	NTU	2.1	2.1	0.5	5.5
Total Organic Carbon (TOC)	mg/L	1.3	1.2	1.4	2.7
Specific Conductance	uS/cm	42	41	12	125
Alkalinity (as $CaCO_3$)	mg/L	18	17	5	51
Color	units	16	17	9	19
pH	units	7.7	7.8	7.1	7.6
Microbiological					
Total Coliform	MPN/100ml	11	11	7	19
Fecal Coliform	MPN/100ml	2	2	2	2

1. Microbioloigical data based on median values

5.0 Water Treatment for Alternative Operational Strategies

5.1 Introduction

Three alternative strategies for operating the SFPUC water system without the Hetch Hetchy Reservoir were identified in Section 4, and the projected raw water quality for each strategy was developed for several hydrological conditions. The objective of this section is to identify potential and appropriate water treatment technologies for those alternatives that would result in water quality that is effectively equivalent to the current finished water quality as summarized in Table 3.2.

During the 1990s, the SFPUC conducted planning studies that examined options for water treatment processes that might be required to meet the (at that time) proposed regulations defined in the 1986 Amendments to the Safe Drinking Water Act and additions to California State (Title 22) regulations. Separate treatability studies were done for both the Hetch Hetchy System and Local (Alameda) source waters (Camp Dresser & McKee 1995a; Camp Dresser & McKee 1995b). Since that time, several of the proposed regulations, including the Stage 1 Disinfectant/Disinfection By-Products Rule (D/DBP), the Interim Enhanced Surface Water Treatment Rule (IESWTR), and the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR) have been promulgated, and the Long Term 2 Enhanced Surface Water Treatment Rule has been proposed. The SFPUC's recent conversion to chloramination was in part carried out to help meet these and future requirements. Although the projected raw water quality conditions in the present study differ somewhat from the raw water quality conditions examined in the earlier SFPUC studies, the information developed in those studies was useful in identifying appropriate treatment for the alternatives discussed in Section 4.

A study of Bay-Delta Water Quality conducted by the California Urban Water Agencies was useful in identifying water quality issues and potential treatment options for the alternative involving Delta diversion (California Urban Water Agencies 1998).

The proposed treatment options described below rely on treatment technologies that are currently in use by the SFPUC, with the possible addition of nanofiltration or reverse osmosis for a portion of the flow in the Delta alternative (Section 5.3). IF SFPUC were to operate the water supply system without the Hetch Hetchy Reservoir in the future, "newer" technologies, such as microfiltration and UV disinfection might be appropriate to meet treatment needs and the increasingly stringent requirements of future Rules and Regulations governing public water systems. However, for purposes of this planning level evaluation, current water treatment methods are specified with the understanding that it would be appropriate to evaluate the newer alternative technologies along with conventional technologies as part of more detailed studies to be carried out regarding the engineering design of new and/or upgraded facilities.

5.2 Water Treatment for Future Without Hetch Hetchy Reservoir Maximizing Don Pedro Diversion

The projected raw water quality for a blend of Tuolumne River water (with maximum use of Don Pedro water) and Local (Alameda) raw water was presented previously in Table 4.2. Because the blend is still primarily Tuolumne River water, the raw water quality is very high relative to other potential raw source waters. (Note that some differences do exist between the Hetch Hetchy and Don Pedro waters. From a treatment standpoint, the most significant differences are microbiological levels (total and fecal coliform) and turbidity, both of which are higher in the Don Pedro water.

The water quality data indicate that a treatment process based on direct filtration is feasible. Such a process would employ preoxidation followed by coagulation/flocculation, filtration, and chloramination. The current use of pH adjustment for corrosion control would continue, although the point of application would need to be coordinated.

Turbidity in the raw water blend will be low, allowing relatively high filtration rates (e.g. perhaps up to 10 gpm/ft^2). Total organic carbon (TOC) levels are low enough in all except the "maximum local" hydrological alternative that the TOC removal requirements of the IESWTR would most likely not apply[2].

To optimize overall treatment costs and process flexibility, and to more closely match treatment process to source water characteristics, having separate treatment facilities for "upstream" sources (Tuolumne River from upstream and Don Pedro direct diversion) and for Local Storage sources may be desirable. The existing SVWTP facility would be used for Local storage sources, and could operate in conventional treatment mode, if necessary for TOC removal and for the higher turbidities that characterize the "Maximum Local" hydrologic alternative[3]. The treatment facility for "upstream" sources would still utilize direct filtration and chloramination, but could operate under different criteria for primary disinfectant and coagulant type/dose, filtration rate, and filter media type. Those criteria would likely resemble the design criteria presented in the SFPUC's March 1995 Hetch Hetchy Treatability study[4] (Camp Dresser & McKee 1995a).

Finished water quality for this alternative would be very high and essentially equivalent to the current quality, except as noted below. This finding is not unexpected, given that the source water would still consist of Tuolumne River and Local water in approximately the same ratio. Filtration of the water from the Tuolumne River sources will eliminate the important water quality differences that exist between current (Hetch Hetchy reservoir) and proposed ("run of river" and Don Pedro Reservoir) raw water sources.

Even with the water treatment suggested above, slight differences in finished water quality between current and this proposed (Maximize Don Pedro) alternative may remain. Depending on removal rates, concentrations of some inorganic constituents (e.g. iron, aluminum) may be

[2] If applicable, the requirement for TOC levels of 2-4 mg/L at <60 mg/L alkalinity is 35% removal. This requirement would likely require much higher coagulant doses and changing operation to conventional treatment, i.e. with sedimentation prior to filtration. A review of Tables 3.4 and 3.5 indicates that the same situation arises (i.e. TOC>2 mg/l) in the case of "Future Demand with Hetch Hetchy Reservoir, Maximum Local" alternative.

[3] The flow from local sources under the "maximum local" alternative is 165 Mgal/d. This "maximum local" alternative is intended to represent average flow during the maximum flow month. According to SFPUC information, the recently expanded SVWTP can handle flows to 160 Mgal/d.

[4] Compliance with the Long Term 2 Enhanced Surface Water Treatment Rule could require modification of existing or proposed disinfectants used at the SFPUCs water treatment plants. The modification would be needed in the future with or without use of the Hetch Hetchy Reservoir.

greater than current levels. However, these concentrations will remain low enough that modifying or adding the treatment processes for these constituents does not appear warranted. Potential MTBE concentrations in the Don Pedro Reservoir source water are of greater concern. The MTBE data are sparse and are limited by varying detection limits. An examination of Table 2.5 indicates one detectable result out of three raw water samples for Don Pedro Reservoir, whereas Hetch Hetchy raw water samples (11 observations) and Calaveras Reservoir raw water samples (7 observations) were all below detectable levels. It is reasonable to assume that the specified process (direct filtration) would not remove MTBE. Any detectable level of MTBE in the finished water, even below California Department of Health Services (DHS) drinking water standards, may be deemed unacceptable and require additional treatment for the water quality to be deemed equivalent. Possible additional treatment methods for MTBE removal in drinking water depending on the chemical matrix of the water include air stripping, granular activated carbon, and advanced oxidation (e.g. H_2O_2/ozone or H_2O_2/UV). The latter methods could be complimentary to other treatment objectives (e.g. pre-oxidation and cryptosporidium inactivation). However, based on a single detectable result in the Don Pedro water, it would be premature to conclude that treatment for MTBE removal would be required. MTBE levels in Don Pedro Reservoir are likely to decline in the future as the result of California's phase-out of MTBE in the fuel supply.

Differences in water quality resulting from drought conditions do not appear to be great enough to warrant a different treatment process, although optimal treatment chemical dosing and filtration rates could change under such conditions.

5.3 Water Treatment for Future Without Hetch Hetchy Reservoir Maximizing Delta Diversion

The inclusion of water from the Delta into the raw water blend will have a greater impact on raw water quality than the Maximize Don Pedro alternative. Reasons for the greater impact include the following:

- The TOC concentration in all but the "maximum upstream" alternative (which involve no Delta water) would dictate that enhanced coagulation be employed for treatment;
- The higher turbidity levels would impact the selection of treatment processes;
- The hardness of finished water would shift form "soft" to "slightly hard", based on U.S. Department of Interior and the Water Quality Association definitions of hardness;
- The TDS concentration would increase to over 100 mg/L in the finished water. This concentration is well below the MCL of 500 mg/L, and would still be considered to be within an optimal range for drinking water, but may be noticeable to residential or industrial users accustomed to the very low TDS of the existing supply;
- A small portion of the water in the Delta is derived from wastewater treatment facility discharges; and
- Levels of other inorganic constituents (aluminum, barium, iron) would increase somewhat.

Based on the blended raw water quality data for this alternative (Table 4.4) full conventional treatment is required, including preoxidation, enhanced coagulation/flocculation, sedimentation, filtration, and chloramination. Ozone would be a likely choice for preoxidant. To meet the TOC removal requirements of the IESWTR, high doses of coagulation (e.g. >30 mg/L alum) would be necessary. Flocculent aid polymers might also be required to enhance sedimentation.

Treatment by the above process would produce a relatively high quality finished water, but that water would have increased levels of hardness and other constituents relative to the SFPUC's existing finished water. Treatment by enhanced softening, in lieu of enhanced coagulation, would reduce the hardness (and possibly other constituents) and still meet requirements of the D/DBP Rule. There would be a cost impact from the increased amount of sludge produced by enhanced softening.

One potential problem associated with use of ozone for preoxidation is the conversion of bromide to bromate. The Stage 1 D/DBP Rule set an MCL for bromine of 10 μg/L. The chemistry of bromate formation is complex and is strongly dependent on both raw water chemistry and the specific design and operating conditions of the ozone treatment facilities. A prediction of bromate concentrations in treated Delta water is beyond the scope of this evaluation. Although a finished water blend comprised of less than 40% Delta water (see Table 4.3) would probably not contain bromate in excess of regulatory limits, the presence of bromate at levels greater than in the existing finished water may be deemed unacceptable.

Treatment to reduce TDS levels would require that some or all of the stream undergo an additional process of nanofiltration or reverse osmosis (NF/RO). The NF/RO process would remove hardness constituents (calcium and magnesium), TOC, bromide, and other inorganic salts, and could produce a finished water quality that is equivalent to the current water quality. The NF/RO process is costly relative to conventional treatment. In addition, the process generates a reject stream that represents a significant fraction (typically 15%) of the source water and contains high levels of salts. Disposal of the reject stream from these treatment processes is an important environmental and economic consideration which may be significant enough to eliminate this treatment option.

MTBE was detected in some (11 out of 48) of the Delta samples at low levels (maximum value was 1.9 ug/L). The calculated average value of 1.1 ug/L includes the non-detect sample values computed at the detection limit of 1 ug/L, so that the actual average value is likely below 1 ug/L. As discussed above for the previous alternative, there is not sufficient information to determine if additional treatment for MTBE removal would be necessary.

As in the previous (Maximizing Don Pedro Diversion) alternative, separate treatment processes for the source waters may be desirable[5]. Under this alternative, the SVWTP (with expanded flow capacity if necessary) would continue to treat water from local storage (including Tuolumne River and Delta water diverted to local reservoirs per Table 4.3), while separate treatment processes would be constructed for water diverted directly from the Delta and for Tuolumne River water. The Delta water would receive full conventional treatment (with enhanced coagulation or softening), and if necessary for TDS, hardness, and/or bromide reduction, NF/RO treatment. The Tuolumne River water would be treated by direct filtration and chloramination, as previously described.

[5] This refers to having the flexibility to segregate the different raw water sources for treatment. Ideally, treatment facilities for the different sources would be located together and could share common components.

As reported in Table 4.3, under drought conditions, use of water from local storage and from the Tuolumne River (upstream) would decrease by approximately 20%, while the quantity diverted from the Delta would increase by the same amount. This drought scenario would impact the sizing of facilities, but not the basic processes or the ability of those processes to meet water quality objectives or to match the current finished water quality.

Under the alternative labeled "maximum upstream", all water is Tuolumne River water from upstream (same as under the Maximizing Don Pedro Diversion alternative) resulting in a higher raw water quality, which could be treated by the facilities identified previously[6]. The same is true for the "maximum local" alternative[7].

5.4 Water Treatment for Future Without Hetch Hetchy Reservoir Using Don Pedro Diversion and an Expanded Calaveras Reservoir.

This alternative is similar to the "Maximizing Don Pedro Diversion" alternative, but relies on increasing the capacity of the Calaveras Reservoir for additional storage of Hetch Hetchy and Don Pedro water. The blended raw water quality is essentially the same for both alternatives, thus treatment requirements would be met using the same processes, i.e. preoxidation, coagulation/flocculation, direct filtration, and chloramination.

If separate treatment (i.e. the existing SVWTP) were used for the local storage water, operation of that plant in "enhanced coagulation" mode might be required under the "maximum local" hydrological scenario because of increased TOC levels. The existing SVWTP can operate in this mode, however, its capacity (up to 160 Mgal/d) is not sufficient to accommodate the "maximum local" alternative flow of 22.6 TAF/month (245 Mgal/d). The difference would need to be provided for, most likely by designing a portion of the new treatment facility for "upstream" sources with flexibility for operating in enhanced coagulation mode.

Because of similarities in finished water quality for this and the "Maximizing Don Pedro Diversion" alternatives, the water quality issues (e.g. MTBE) discussed in Section 5.2 also apply to this alternative.

[6] If separate treatment facilities are constructed for Delta water, they will need to be designed to process Tuolumne River water also.

[7] It is EOA's understanding that the "maximum upstream" and "maximum local" alternatives refer to relatively short-term hydrological conditions. Thus, the projected flows are given in TAF/month.

6.0 Discussion

6.1 Limitations of Water Quality Evaluation

The analysis presented herein is as comprehensive as possible given the available information and data. Nevertheless, it should be clear that there are limitations to this type of evaluation. In addition to the data limitations discussed in Section 2.3.1, other important limitations are discussed briefly below.

<u>It was assumed that the water quality of each raw water source will not change appreciably in the future</u>. The raw source waters that comprise this evaluation include Hetch Hetchy (Tuolumne River) water, Don Pedro water, San Joaquin Delta water, and Local water. It was assumed that the available monitoring data for these source waters is representative of the future water quality for these source waters. If the water qualities of these source waters were to change in the future, the relative water quality of the future finished water will likely be impacted. The relative extent to which those changes would impact the results of this planning level evaluation will depend on which source waters change, the relative magnitude of the change, operations of the integrated water supply system (i.e. whether that portion of the water gets diluted with other water and/or treated), and the efficiency of water treatment relative to the changes in water quality.

<u>The analysis was limited by the available data</u>. The analysis described herein is based on a compilation of the currently available data and information from all agencies that monitor the raw and treated source waters of interest. Based on the data summaries presented herein, it should be clear that in some cases, the available data were quite sparse and/or limited because many of the data were reported below detectable limits. Further, the analytical methods employed were not consistent between source waters for all constituents, and there was substantial variability among the analytical detection limits employed. Finally, data were only available for a representative, yet limited subset of all of the contaminants that may be of potential concern.

Given the data that were available and quantifiable, it seems reasonable to conclude that this analysis provides a concise summary of the relative water qualities of the potential future raw source waters. However, it is not possible to estimate or predict concentrations of particular constituents that were not monitored. Because there are chemicals that are known or thought to cause adverse human health impacts in extremely low levels, consideration must be given to the possibility that one or more of the source waters contain contaminants of concern that were not monitored. (For example, the California Department of Health Services has imposed in interim action level of 0.020 ug/L for N-Nitrosodimethylamine and may consider an MCL as low as 0.002 ug/L). Therefore, if the potential restoration of Hetch Hetchy Valley is to move forward beyond the planning level stage, detailed engineering and health impact studies would be prudent and warranted. The extent to which the different water supply options could be impacted by source waters containing highly toxic chemicals (even in low or undetectable levels) should be one component addressed in such studies.

<u>The projected water qualities do not account for variability and uncertainty</u>. The projected raw qualities for the three alternatives investigated (Tables 4.2, 4.4, and 4.6) are based on average

concentrations. For a screening level assessment such an approach is appropriate, however it should be clear that in reality the concentrations of each of the constituents in each of the alternatives will have some associated variability. The extent to which that variability would impact how water would need to be treated to achieve the desired finished water quality is not accounted for in this planning level evaluation.

Higher constituent concentrations in raw water do not necessarily imply increased health risk. The analysis presented herein summarizes projected concentrations of constituents in raw and treated waters. The analysis provides a perspective on relative water qualities rather than a quantitative estimate of adverse human health effects associated with contaminant levels in drinking water. It should, however, be understood that not all constituents in water adversely affect human health and that increased concentrations of particular constituents do not necessarily imply an increased risk to human health.

6.2 Additional Discussion on Data Analysis for Selected Constituents

6.2.1 Turbidity

The turbidity levels in raw source waters (Hetch Hetchy, Don Pedro, Delta, and local waters) varied from a low of 0.5 NTU for Hetch Hetchy water to 12.7 NTU for Delta water (Table 2.13). The turbidity of the Hetch Hetchy treated water was 0.4 NTU and product water from the SVWTP was 0.1 NTU.

If the Hetch Hetchy Reservoir is not part of the SFPUC water supply system in the future, it is very likely that the turbidity of the Tuolumne River water below Hetch Hetchy Valley will be higher than it is currently. Depending on actual operation of the water supply system, this increased turbidity of Tuolumne River water could be seen as far downstream as the SVWTP. Given that without the Hetch Hetchy Reservoir, water treatment will need to include filtration and disinfection system-wide prior to distribution (refer to Section 5), the water treatment system would need to be designed to reduce the turbidity to levels in the range of 0.1-0.5 NTU. Based on the data presented in Sections 2, 3, and 5, reductions to such levels appear technically feasible.

6.2.2 Trihalomethanes

The total trihalomethane data presented in Section 2 for the Hetch Hetchy, Don Pedro, and local supplies represent measured total THM concentrations in those source waters. The total THM data presented in Section 2 for the Delta supply (for the Banks Pumping Station on the California Aqueduct in particular) represents THM formation potential rather than Total THM concentrations.

As noted previously, THM formation potential is a measure of the capacity for THMs to form when disinfectants are added during the water treatment process. The extent to which THMs actually form during the water treatment process depends on a number of factors, including the removal of natural organic matter and type of treatment and disinfection employed. One reason for using chloramine disinfection rather than free chlorine disinfection is to reduce the potential for disinfection by-product formation (THMs are disinfection by-products).

Without monitoring data or more detailed analysis than was available for this study, it is difficult to know what the levels of THMs would be in Delta water after treatment. However, it should be clear that the TTHM formation potential of blended raw waters will vary with the proportion of Delta water making up that blend. It is also clear that treatment processes for Delta water would need to specifically address the higher THM potential of this raw water source. Thus in Section 5.3, the specified technology for (separate) treatment of Delta water includes enhanced coagulation (for reduction of TOC, a THM precursor), preoxidation with ozone, and use of chloramine for secondary disinfection.

6.2.3 MTBE

MTBE (methyl tertiary-butyl ether) is a chemical compound that is manufactured by the chemical reaction of methanol and isobutylene. MTBE is produced in very large quantities (over 200,000 barrels per day in the U.S. in 1999) and is almost exclusively used as a fuel additive in motor gasoline. It is one of a group of chemicals commonly known as "oxygenates" because they raise the oxygen content of gasoline. At room temperature, MTBE is a volatile, flammable and colorless liquid that dissolves rather easily in water.

MTBE has been used in U.S. gasoline at low levels since 1979 to replace lead as an octane enhancer (helps prevent the engine from "knocking"). Since 1992, MTBE has been used at higher concentrations in some gasoline to fulfill the oxygenate requirements set by Congress in the 1990 Clean Air Act Amendments. Oxygen helps gasoline burn more completely, reducing harmful tailpipe emissions from motor vehicles. However, MTBE has been found in drinking water supplies. For this reason, the State of California banned the use of MTBE in fuels as of January 1, 2004, and several other states are also phasing out its use. Action at the federal level is still being debated.

MTBE is a regulated drinking water contaminant in California, with a primary maximum contaminant level of 13 µg/L that addresses health concerns and a secondary MCL of 5 µg/L. California also has a public health goal of 13 µg/L for MTBE in drinking water.

EPA has not set a national standard for MTBE, however EPA is continuing to study both the potential health effects and the occurrence of MTBE. MTBE is on the 1998 Candidate Contaminant List (CCL) and the Draft CCL2 (April 2004). In terms of human health risks, researchers have limited data about what the health effects may be if a person swallows (ingests) MTBE. EPA's Office of Water has concluded that available data are not adequate to estimate potential health risks of MTBE at low exposure levels in drinking water but that the data support the conclusion that MTBE is a potential human carcinogen at high doses (source: http://www.epa.gov/mtbe/water.htm#concerns).

MTBE was always below detectable limits (0.5 µg/L) in the Hetch Hetchy raw water (11 observations) and the local water (7 observations). MTBE was below detectable limits in 2 of 3 observations for the Don Pedro water (1 detected observation at 5 µg/L) and in 41/52 observations for Delta water (average concentration of 1.1 µg/L). While all of these observations are below regulated levels for drinking water, the potential for MTBE pollution of drinking water should be considered if the potential restoration of Hetch Hetchy Valley is to move forward beyond the planning level stage.

6.2.4 Total Organic Carbon

Total Organic Carbon (TOC) is a commonly monitored constituent because it is relatively easy and inexpensive to monitor and the results give a general indication of a water's characteristics with respect to pollution (Metcalf and Eddy 2003). Increased organic carbon in drinking water may be linked to an increase in disinfection by-products and the potential formation of carcinogenic compounds.

Review of the data presented in Section 2 indicates that the TOC average concentration in the Hetch Hetchy raw water is 1.4 mg/L, 4.4 mg/L in the local water, and 3.8 mg/L in the Delta water. Don Pedro water has a reported average TOC concentration of 0.5 mg/L. The Don Pedro TOC concentration is, however, based on a single sample. If the potential restoration of Hetch Hetchy Valley is to move forward beyond the planning level stage, the TOC of Don Pedro water will need to be characterized more comprehensively.

6.2.5 Arsenic

The current federal drinking water standard for arsenic is 50 µg/L. A new more stringent limit of 10 µg/L will take effect in 2006. On April 23, 2004 California set a public health goal of 0.004 µg/L (4 parts per trillion) arsenic in drinking water. The public health goal means arsenic would not cause more than one additional cancer case in a population of one million people drinking two liters of water daily for 70 years. Based on this new public heath goal, the California Department of Health Services must now use the new state goal to create a standard for the maximum allowable level of arsenic in drinking water, which by law must be as close to the health goal as is economically and technically feasible.

Review of the data presented in Section 2 indicates that the average concentration of arsenic in each of the raw source waters is very similar (~ 2 µg/L). However close inspection of Tables 2.3, 2.4, 2.5, 2.7, 2.8, and 2.9 indicates that there may be slight differences in the concentrations of arsenic in the source waters considered in this analysis.

Hetch Hetchy raw water was analyzed 11 times for arsenic and the results were always below detectable levels. The detection limit ranged from 1 to 20 µg/L. Don Pedro water was analyzed 6 times for arsenic, and 5 of those observations were below the detectable limit of 2 µg/L. The other observation was reported at the detection limit (2 µg/L). South Bay aqueduct water (Delta water) was analyzed 6 times for arsenic, and all observations were reported above the detection limit. The average concentration of arsenic in these samples was 5 µg/L with a maximum reported value of 13 µg/L. California aqueduct water (Delta water – Banks pumping station) was analyzed 109 times for arsenic, with 108 observations reported above the detection limit, with a maximum concentration of 3 µg/L. The average concentration of arsenic in these samples was 2 µg/L. Calaveras Reservoir water (local water) was analyzed 9 times for arsenic and 6 of the observations were below detectable levels, with a maximum concentration of 3 µg/L.

Given the potential public health importance of arsenic in drinking water and the new California public health goal (which at this point in time is below analytical limits), the potential for arsenic contamination should be considered carefully in any water supply strategy that may be used in the future for the SFPUC system.

6.2.6 Giardia and Cryptosporidium

Cryptosporidium and giardia are protozoan parasites that are of particular concern in drinking water because of their resistance to water treatment disinfection. Both pathogens have been associated with waterborne disease outbreaks. Ingestion of viable giadia cysts or cryptosporidium oocysts in sufficient quantities can cause acute gastrointestinal illness. Adverse health effects from ingestion of cryptosporidium may be severe for sensitive subpopulations (e.g., infants, AIDS patients, the elderly) and may include the risk of death.

Existing drinking water regulations require public water systems that use surface water sources and provide filtration to achieve at least a 99 percent removal of cryptosporidium. New data on cryptosporidium infectivity, occurrence, and treatment indicate that current treatment requirements are adequate for the majority of systems, but there is a subset of systems with higher vulnerability to cryptosporidium where additional treatment is necessary (http://www.epa.gov/safewater/lt2/pdfs/fact_lt2.pdf).

Under the currently proposed federal drinking water regulations (Proposed Long-Term 2 Enhanced Surface Water Treatment Rule), systems initially conduct source water monitoring for cryptosporidium to determine their treatment requirements. Filtered systems will be classified in one of four risk categories based on their monitoring results. EPA projects that the majority of systems will be classified in the lowest risk bin, which carries no additional treatment requirements. Systems classified in higher risk bins must provide 90 to 99.7 percent additional reduction of cryptosporidium levels. The regulation specifies a range of treatment and management strategies that systems may select to meet their additional treatment requirements. All unfiltered systems must provide at least 99 to 99.9 percent inactivation of cryptosporidium, depending on the results of their monitoring.

For this water quality evaluation, giardia and cryptosporidium concentrations in raw source water supplies and the treated Hetch Hetchy supply were presented in Tables 2.3b (Hetch Hetchy raw water), 2.6 (Don Pedro), 2.8b (California Aqueduct), 2.9b (Calaveras Reservoir), and 2.10 (Hetch Hetchy treated water). A comparison of the average concentrations for those waters was presented in Table 2.12b. Inspection of the data presented in those tables, indicates the following:

- ◇ Hetch Hetchy raw water: 138 of 161 observations for giardia were below detectable limits, and 154 of 161 observations for cryptosporidium were below detectable limits. In most cases the detection limit was 0.1 cysts /L for giardia and 0.1 oocysts/L cryptosporidium. The maximum reported concentrations were 1.0 cyst/L for giardia and 0.1 oocysts/L for cryptosporidium.
- ◇ Don Pedro raw water: Giardia and cryptosporidium data are from the Modesto Reservoir. 60 of 62 observations for giardia were below detectable limits, and 61 of 71 observations for cryptosporidium were below detectable limits. In most cases the detection limit was 0.1 cyst/L for giardia and 0.1 oocyst/L for cryptosporidium. The maximum reported concentrations were 0.2 cysts/L for giardia and 0.4 oocysts/L for cryptosporidium.

- ◇ California Aqueduct water: Giardia concentrations were below detectable limits in all of 20 observations, with detection limits ranging from 0.03 to 0.3 cysts/L. Cryptosporidium concentrations were below detectable observations in 19 of 20 observations. The average detection limit for these observations was ~0.1 oocyst/L and the one detectable observation occurred at a concentration of 1.7 oocysts/L.
- ◇ Calaveras Reservoir: 37 of 39 observations were below detectable limits for both giardia and cryptosporidium. The detection limits were 0.1 cysts/oocysts /L between January and November 2001, and 0.01cysts/oocysts /L thereafter. The maximum reported concentrations were 1.6 cyst/L for giardia and 1.6 oocysts/L for cryptosporidium.
- ◇ Hetch Hetchy treated water: Giardia and cryptosporidium data are from the SFPUC College Hill Outlet and University Mound Reservoir monitoring locations. Giardia concentrations were below detectable limits in 161 of 166 observations , and cryptosporidium concentrations were below detectable limits in 160 of 166 observations. The detection limits were 0.1 cysts/oocysts /L between January and November 2001, and 0.01cysts/oocysts /L thereafter. The maximum observed concentration of giardia was 0.04 cysts/L and the maximum observed concentration of cryptosporidium was 0.1 oocyst/L (note that this concentration was observed 4 times, and in each case the observed concentration was reported at the limit of detection).

For these observations, the results represent the total counts of the protozoa in the source water and do not differentiate between cysts/oocysts that are viable from those that are nonviable nor those that have identifying structures from those that have empty structures. Based on these available data, it is difficult to assess the potential relative differences between the source waters relative to giardia and/or cryptosporidium concentrations. Nevertheless, given the potential public health significance of giardia and/or cryptosporidium in drinking water, the potential for microbiological contamination should be considered carefully in any future water supply strategy that may be employed for the SFPUC system.

6.2.7 Variation in South Bay Aqueduct Water Quality

A data summary for the monitoring results of the South Bay Aqueduct (Delta water) was presented previously in Table 2.7. From a close inspection of the raw data used to generate Table 2.7 it can be seen that several constituents had marked increases in concentrations during the 1998 – 2000 time period. The constituents of note were aluminum, barium, iron, and manganese. A summary of those observations is provided in Table 6.1. Because data were not available for the time period of 2001 through the present, it is not known whether the 1998-2000 elevated concentrations are representative of current conditions. Nevertheless, if South Bay Aqueduct water is to be an important component in a future water supply strategy for SFPUC, the potential for such changes in water quality should be considered carefully and water treatment facilities should be designed to account for the potential of such variability.

Table 6.1. Selected South Bay Aqueduct Monitoring Results

Year	Aluminum ug/l	Barium ug/l	Iron ug/l	Manganese ug/l
1995	13	59	18	<3
1996	16	33	20	<3
1997	13	40	23	4
1998	780	300	800	1300
1999	250	130	780	280
2000	220	220	620	390

6.3 Potential Water Quality Impacts of Increased Tourism in Hetch Hetchy Valley

Currently Yosemite Park experiences approximately 3.3 million visitor days each year (http://www.nps.gov/yose/pphtml/facts.html) . The majority of the visitors are day users that remain in Yosmite Valley and the immediately adjacent park lands, which are not in the Hetch Hetchy watershed (CH2M HILL 1995). Roughly 5% of the visitor nights in Yosemite National Park are by overnight backcountry users. The number of wilderness use nights recorded for Yosemite National Park for the Years 1990 through 2003 are presented in Table 6.2.

Table 6.2. Wilderness Use Nights in Yosemite National Park

Year	*Use Nights*
1990	101,990
1991	117,978
1992	119,816
1993	115,999
1994	116,273
1995	109,532
1996	125,498
1997	96,666
1998	76,350
1999	80,780
2000	98,503
2001	103,240
2002	118,824
2003	93,709

(Data Source: SFPUC Sanitary Surveys 1997-2003, CH2MHIll 1995)

On an annual basis, between 26 and 38% of Yosemite's wilderness use occurs in the Hetch Hetchy and Eleanor watersheds (San Francisco Public Utilities Commission 1997; San Francisco Public Utilities Commission 1998; San Francisco Public Utilities Commission 1999; San Francisco Public Utilities Commission 2000; San Francisco Public Utilities Commission 2001; San Francisco Public Utilities Commission 2002; San Francisco Public Utilities Commission 2003). Therefore, it is estimated that there are between 20,000 and 50,000 use nights annually in these watersheds. The Lake Eleanor watershed receives very little use; therefore the bulk of these use nights occur in the Hetch Hetchy watershed.

It is reasonable to assume that if the Hetch Hetchy Valley were restored, the number of visitors (both day users and backcountry users) to this portion of Yosemite National Park would increase. The potential extent of this increase is unknown. However, increased visitation in Hetch Hetchy Valley raises potential water quality concerns, as there would be the possibility for increased contamination in the Tuolumne River from people, animals, vehicles, fire, chemicals, and erosion.

Quantifying the potential contamination increases in the Tuolumne River from increased visitation of Hetch Hetchy Valley is beyond the scope of this planning level water evaluation. However, it is clear that a well thought out watershed management plan would be a necessary component for the future of Hetch Hetchy Valley. Further, minimizing chemical and microbiological contamination in the Valley should be facilitated through an integrated transportation and recreation plan (i.e. minimizing the number of vehicles allowed in the Valley, placing campgrounds, toilets, and/or water treatment facilities in areas that minimize Tuolumne River water quality vulnerability, and limiting backcountry usage in areas which are particularly vulnerable to water quality impacts).

7.0 Conclusions

Environmental Defense is evaluating the feasibility of restoring the Hetch Hetchy Valley and is therefore exploring alternatives for the water supply, water quality and power benefits currently made possible by the Hetch Hetchy Reservoir. Restoring the Hetch Hetchy Valley would involve technical, operational and political considerations. This technical memorandum provides a planning level evaluation of existing and potential future water quality, both with and without the Hetch Hetchy Reservoir, for water supply alternatives being evaluated by Environmental Defense. This planning level water quality evaluation is based on available data and information and includes:

1. A summary of the existing SFPUC Hetch Hetchy water system and an overview of current operations;
2. Data summaries for raw waters that are representative of SFPUC source waters;
3. Data summaries for treated waters that are representative of SFPUC delivered water;
4. A summary of current finished (treated) water quality;
5. Estimated raw water quality for future (2030) demand, assuming that the Hetch Hetchy Reservoir continues to be a part of the water supply system;
6. Estimated raw water quality for future (2030) demand, for three alternative operational strategies to the Hetch Hetchy Reservoir; and
7. A description of the types of water treatment that would be needed for the alternative operational strategies so that future finished water would be of similar quality to the current finished water.

The financial, water supply, and political ramifications of operating the SFPUC water system without the Hetch Hetchy Reservoir are beyond the scope of this planning level water quality evaluation. Based on the results presented herein, from a screening level water quality perspective, there does not appear to be any technical reason that the SFPUC Hetch Hetchy water supply system could not be operated without the Hetch Hetchy Reservoir provided that adequate water treatment facilities were put in place and operated to meet state and federal drinking water regulations. If such an operational strategy were to be pursued, engineering and health effects investigations would be needed to optimize water quality and treatment issues. Further, in a restored Hetch Hetchy Valley watershed practices would have to be developed, implemented and enforced to minimize the potential contamination of source waters associated with increased human and animal presence.

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Attachment 1: List of Contaminants of Possible Concern

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
VOCs	Acetone	X							X	X	
	Acrolein	X	X								X
	2-Butanone	X									
	Benzene	X	X		X	X				X	X
	Bromobenzene			X							
	Bromochloromethane			X							
	Bromodichloromethane		X	X							
	Bromoform	X	X	X							
	Bromomethane		X	X							
	Carbon Disulfide	X						X			X
	Carbon Tetrachloride	X			X	X		X			
	Chlorobenzene	X	X		X		X			X	X
	Chlorodibromomethane	X		X							
	Chloroethane	X	X	X			X				
	Chloroform	X	X	X			X		X	X	X
	Chloromethane	X	X	X			X				
	1,2-Dibromoethane	X						X	X		X
	Dibromomethane			X							
	Dibromochloropropane	X									
	1,1-Dichloroethane	X	X	X		X	X				
	1,1-Dichloroethene	X	X		X	X	X				
	1,2-Dichlorobenzene	X	X			X	X				
	O-Dichlorobenzene				X		X			X	
	P-Dichlorobenzene				X		X				
	1,2-Dichloroethane	X			X	X	X	X	X	X	X
	1,2-Dichloroethene, Trans-	X	X		X	X	X				
	1,2-Dichloroethene, Cis-				X	X	X				
	Dichloromethane				X	X	X				
	2,2-Dichloropropane			X			X				
	1,3-Dichloropropane			X			X				
	1,1-Dichloropropene			X			X				
	1,2-Dichloropropane	X	X		X	X	X				X
	1,3-Dichlorobenzene	X	X	X			X				
	1,3-Dichloropropene, Cis-	X	X	X		X	X				X
	1,3-Dichloropropene, Trans-	X	X	X		X	X				X
	1,4-Dichlorobenzene	X	X			X	X				
	Dichlorobenzene	X					X				
	Dichloroethane	X									
	Ethyl Benzene	X	X		X	X					X
	Fluorotrichlorommethane			X							
	2-Hexanone	X									
	Methane	X									
	Methyl Isobutyl Ketone	X							X	X	X
	Methylene Chloride	X					X		X	X	X
	Monochlorobenzene					X	X				
	Nitrobenzene		X	p							
	O-Xylene	X									
	Styrene	X			X	X	X		X		X
	1,1,2,2-Tetrachloroethane	X	X		X	X	X		X		
	1,1,1,2-Tetrachloroethane			X			X				
	Tetrachloroethane	X					X				
	Tetrachloroethylene	X	X		X	X	X		X		X
	Toluene	X	X		X	X				X	X
	Total Xylenes	X			X	X			X	X	
	1,1,1-Trichloroethane	X	X		X	X	X				X
	1,1,2-Trichloroethane	X	X		X	X	X				
	1,2,3-Trichlorobenzene	X	X	X	X		X				
	1,2,4-Trichlorobenzene	X	X		X	X	X				
	Trichloroethylene	X	X		X	X	X		X		X
	Trichlorofluoroethane	X				X					
	1,1,2-Trichloro-1,2,2-Fluoroethane					X					
	Vinyl Chloride	X	X		X	X					
NON-VOLATILE S											
	Alachlor			p	X	X	X				
	4-Aminobiphenyl	X									
	Atrazine				X	X	X				
	Bentazon					X					
	Benzidine	X	X								
	Bis(2-Chloroethyl) Ether	X	X				X				
	Butyl Benzyl Phthalate	X	X								
	Carbofuran					X		X			
	2-Chlorophenol	X	X				X				X
	3,3'-Dichlorobenzidine	X	X				X		X		
	2,4-D	X				X	X	X			

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Dalapon					X					
	1,2,Dibromo-3-Chloropropane				X	X					
	Di(2-Ethylhexyl)Adipate				X	X					
	Di(2-Ethylhexyl)Phthalate	X	X		X	X					X
	Dinoseb				X	X					
	Diquat				X	X		X			X
	2,4-Dichlorophenol	X	X	p			X				
	2,4-Dimethylphenol	X	X				X				
	2,4-Dinitrophenol	X	X	p							
	2,4-Dinitrotoluene	X	X	p							
	2,6-Dinitrotoluene	X	X	p							
	1,2-Dibromo-3-Chloropropane	X									
	Dibenzofuran	X									
	Dibenzofurans, Chlorinated	X					X				
	Dichlorvos	X						X			X
	Dimethoate	X						X			X
	1,3-Dinitrobenzene	X									
	Di-N-Butyl Phthalate	X	X						X		
	Di-N-Octyl Phthalate		X								
	1,2-Diphenylhydrazine	X	X								
	Disulfoton	X		p				X			
	Endothall				X	X					
	Ethion	X						X			
	Ethylene Dibromide				X	X					
	Glyphosate				X	X		X	X		X
	Hexachlorobenzene	X	X		X	X	X	X	X		
	Hexachlorobutadiene	X	X	X			X		X		X
	Hexachloroethane	X	X				X				
	Kepone	X									
	Lindane				X	X	X	X			X
	1-Methylnaphthalene	X									
	2-Methylnaphthalene	X									
	Methyl-T-Butyl Ether	X									
	Molinate			p		X					
	2-Nitrophenol		X								
	4-Nitrophenol	X	X								
	N-Nitrosodi-N-Propylamine	X									X
	N-Nitrosodiphenylamine	X									X
	Oxamyl				X	X		X			
	Parathion	X					X	X			
	Pentachlorobenzene	X					X				
	Pentachlorophenol	X	X		X	X	X				X
	Phenol	X	X						X	X	X
	Phorate	X						X			
	Picloram				X	X					
	Simazine				X	X					
	Thiobencarb					X					
	Toxaphene	X	X		X	X	X				
	2,4,5-Trichlorophenol	X					X				
	2,4,6-Trichlorophenol	X	X	p			X				
	Trichlorobenzene	X					X				
	2,4,5-Tp (Silvex)				X	X					
Pesticides and Herbicides											
	Abamectin							X			
	Acephate							X			
	Aldrin	X	X	X				X			X
	Aminocarb							X			
	Amitraz							X			
	Amitrole						X	X	X		X
	Anilazine							X			
	Azocyclotin							X			
	Azinphos-Ethyl							X			
	Azinphos-Methyl							X			
	Benalaxyl							X			
	Bendiocarb							X			
	Benomyl						X	X			X
	Bentazone							X			
	Bifenthrin							X			
	Binapacryl							X			
	Bioresmethrin							X			
	Bitertanol							X			
	Bromophos							X			
	Bromophos-Ethyl							X			
	Bromopropylate							X			
	Buprofezin							X			

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Butocarboxim							X			
	Cadusafos							X			
	Camphechlor							X			X
	Captafol							X			
	Captan							X			
	Carbendazim							X			X
	Carbosulfan							X			
	Cartap							X			
	Chinomethionat							X			
	Chlorbenzilate							X			
	Chlordane	X	X		X	X	X	X			X
	Chlordimeform							X	X		
	Chlorfenvinphos							X			
	Chlormequat							X			
	Chlorpyrifos-Methyl							X			
	Chlorthalonil							X			
	Cis-Chlordane	X									
	Clethodim							X			
	Coumaphos							X			
	Crufomate							X			
	Cyanofenphos							X			
	Cycloxydim							X			
	Cyfluthrin							X			
	Cyhexatin							X			
	Cyhalothrin							X			X
	Cypermethrin							X			X
	Cyromazine							X			
	Daminozide							X			
	Ddd, P,P'-	X					X				X
	Dde, P,P'-	X		p			X				X
	Ddt, P,P'-	X	X				X	X			X
	Deltamethrin							X			X
	Demeton							X			
	Demeton-S-Methyl							X	X		
	Demeton-S-Methylsulphon							X			
	Dialifos							X			
	Dithianon							X			
	Diazinon	X		p				X	X		
	Diflubenzuron							X			X
	Dichlofluanid							X			
	Dicloran							X			
	Dieldrin	X	X	X				X			X
	Dimethipin							X			
	Dinocap							X			
	Dioxathion							X			
	Diphenyl							X			
	Diphenylamine							X			
	Dithiocarbamates							X			X
	Dodine							X			
	Edifenphos							X			
	Endosulfan	X	X				X	X			X
	Endosulfan Sulfate	X									
	Endosulfan, Alpha	X									
	Endosulfan, Beta	X									
	Endrin	X	X		X	X		X			X
	Endrin Aldehyde	X	X								
	Endrin Ketone	X									
	Ethephon							X			
	Ethiofencarb							X			
	Ethoxyquin							X			
	Ethoprophos							X			
	Ethylene Thiourea (ETU)							X			X
	Etofenprox							X			
	Etrimfos							X			
	Fenabutatin Oxide							X			
	Fenamiphos							X			
	Fenarimol							X			
	Fenbuconazole							X			
	Fenchlorphos							X			
	Fenitrothion							X			X
	Fenpropathrin							X			
	Fenpropimorph							X			
	Fenpyroximate							X			
	Fensulfothion							X			
	Fenthion							X			

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Fentin							X			
	Fenvalerate							X			X
	Flucythrinate							X			
	Flumethrin							X			
	Flusilazole							X			
	Folpet							X			
	Formothion							X			
	Glufosinate-Ammonium							X			
	Guazatine							X			
	Haloxyfop							X			
	Heptachlor	X	X		X	X	X				X
	Heptachlor Epoxide	X	X		X	X	X				
	Hexachlorocyclopentadiene	X	X		X						X
	Hexaconazole							X			
	Hexithiazox							X			
	Hydrogen Phosphide							X			X
	Imazalil							X			
	Iprodione							X			
	Isofenphos							X			
	Leptophos							X			
	Malathion	X						X			
	Maleic Hydrazide							X			
	Mancozeb						X	X			
	Mecarbam							X			
	Metalaxyl							X			
	Methacrifos							X			
	Methamidophos							X			
	Methidathion							X			
	Methiocarb							X			
	Methoprene							X			
	Methoxychlor	X			X	X	X				
	Methyl Bromide							X	X		X
	Metiram						X	X			
	Mevinphos							X			
	Monocrotophos							X			
	Myclobutanil							X			
	Nitrofen						X	X			
	Omethoate							X			
	Oxydemeton-Methyl							X			
	Paclobutrazol							X			
	Paraquat							X			X
	Parathion-Methyl						X	X			X
	Peconazole							X			
	Permethrin							X			X
	Phenothrin							X			X
	Phenthoate							X			
	2-Phenyl-Phenol							X			
	Phosalone							X			
	Phosmet							X			
	Phosphamidion							X			
	Phoxim							X			
	Piperonyl Butoxide							X			
	Pirimicarb							X			
	Pirimiphos-Methyl							X			
	Prochloraz							X			
	Procymidone							X			
	Profenofos							X			
	Propamocarb							X			
	Propargite							X			
	Propham							X			
	Propiconazole							X			
	Propylene Thiourea (PTU)							X			X
	Propoxur							X			
	Pyrazophos							X			
	Pyrethrins							X			
	Quintozene							X			X
	Sec-Butylamine							X			
	2,4,5-T							X			
	Tebuconazole							X			
	Tebufenozide							X			
	Tecnazene							X			X
	Teflubenzuran							X			
	Thiabenazde							X			
	Thiocarbamates										X
	Thiodicarb							X			

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Thiometon							X			
	Thiophanate-Methyl							X			
	Tolclofos-Methyl							X			
	Tolylfluanid							X			
	Trans-Chlordane	X									
	Triadimefon							X			
	Triadimenol							X			
	Triazphos							X			
	Trichlorfon							X			X
	Triforine							X			
	Vamidothion							X			
	Vinclozolin							X			
PAHs	Acenaphthene	X	X				X				
	Anthracene	X	X				X				
	Benzo(A)Anthracene	X	X				X				
	Benzo(A)Pyrene	X	X		X	X	X				
	Benzo(B)Fluoranthene	X	X				X				
	Benzo(J)Fluoranthene	X					X				
	Benzo(K)Fluoranthene	X	X				X				
	Benzo(Ghi)Perylene	X	X				X				
	Benzofluoranthene	X					X				
	Chrysene	X	X				X				
	Dibenzo(A,H)Anthracene	X	X				X				
	Dibenz(A,J)Acridine	X					X				
	Dibenzo(A,H)Anthracene	X					X				
	7H-Dibenzo(C,G)Carbazole	X					X				
	Dibenzo(A,E)Pyrene	X					X				
	Dibenzo(A,H)Pyrene	X					X				
	Dibenzo(A,I)Pyrene	X					X				
	Fluoranthene	X	X				X				
	Fluorene	X	X				X				
	Indeno(1,2,3-Cd)Pyrene	X	X				X				
	3-Methylcholanthrene	X					X				
	Naphthalene	X	X	X			X		X		
	Phenanthrene	X	X				X				
	Pyrene	X					X				
Metals											
	Aluminum	X				X			X		
	Antimony	X	X		X	X					
	Arsenic	X	X		X	X					X
	Asbestos	X	X		X	X					X
	Barium	X			X	X					X
	Beryllium	X	X		X	X					X
	Cadmium	X	X		X	X	X				X
	Chromium	X	X		X	X					X
	Chromium (Vi) Trioxide	X									
	Chromium, Hexavalent	X									
	Cobalt	X									
	Copper	X	X		X				X		
	Cyanide	X	X		X	X					
	Fluoride				X						X
	Lead	X	X		X		X		X		X
	Manganese	X									X
	Mercury	X	X		X	X	X				X
	Nickel	X	X			X					X
	Nitrate	X			X	X					X
	Nitrite	X			X	X					X
	Phosphorus	X									
	Platnium										X
	Selenium	X	X		X	X					X
	Silver	X	X								
	Thallium		X		X	X			X		X
	Tin										X
	Titanium										X
	Vanadium	X									X
	Zinc	X	X								
Radioactive											
	Americium-241	X									
	Bismuth-212	X									
	Bismuth-214	X									
	Cesium-137	X									
	Cobalt-60	X									
	Iodine-131	X									

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Lead-210	X									
	Lead-212	X									
	Lead-214	X									
	Plutonium	X									
	Plutonium-238	X									
	Plutonium-239	X									
	Plutonium-240	X									
	Polonium-210	X									
	Potassium-40	X									
	Radium	X									
	Radium-224	X									
	Radium-226	X			X	X					
	Radium-228	X				X					
	Radon	X									
	Radon-222	X									
	Sodium-22	X									
	Strontium-90	X				X					
	Sulfur-35	X									
	Technetium-99	X									
	Thorium	X									
	Thorium-227	X									
	Thorium-228	X									
	Thorium-230	X									
	Thorium-234	X									
	Thoron (Radon-220)	X									
	Tritium	X				X					
	Uranium	X				X					
	Uranium-233	X									
	Uranium-234	X									
	Uranium-235	X									
Dioxins/Furans											
	1,2,3,4,6,7,8-Heptachlorodibenzo-P-Dioxin	X					X				X
	1,2,3,4,6,7,8-Heptachlorodibenzofuran	x					X				X
	Heptachlorodibenzofuran	X					X				X
	Heptachlorodibenzo-P-Dioxin	X					X				X
	Hexachlorodibenzofuran	X					X				X
	Hexachlorodibenzo-P-Dioxin	X					X				X
	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	X					X				X
	Octachlorodibenzo-P-Dioxin	X					X				X
	2,3,4,7,8-Pentachlorodibenzofuran	X					X				X
	1,2,3,7,8-Pentachlorodibenzo-P-Dioxin	X	X		X		X				X
	Pentachlorodibenzofuran	X					X				X
	Pentachlorodibenzo-P-Dioxin	X					X				X
	2,3,7,8-Tetrachlorodibenzofuran	X					X				X
	2,3,7,8-Tetrachlorodibenzo-P-Dioxin	X					X				X
	Tetrachlorodibenzofuran	X					X				X
	Tetrachlorodibenzo-P-Dioxin	X					X				X
PCBs											
	Aroclor	X			X		X				
	Aroclor 1016	X	X				X				
	Aroclor 1221	X	X				X				
	Aroclor 1232	X	X				X				
	Aroclor 1242	X	X				X				
	Aroclor 1248	X	X				X				
	Aroclor 1254	X	X				X				
	Aroclor 1260	X	X				X				
Other											
	Acetaldehyde								X		X
	Acetic anhydride								X		
	Acetoacetanilide								X		
	Acetochlor			p							
	Acetone cynahydrin								X		
	Acetonitrile								X	X	X
	Acrylamide				X						X
	Acrylic Acid								X		
	Acrylonitrile	X							X		X
	Aldicarb			X			X	X			X
	Aldicarb Sulfone			X							
	Aldicarb Sulfoxide			X							
	Alkanes, C10-C13, Chloro								X		
	Allethrins										X
	1-Amino anthraquinone								X		

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Aminoimino methanesulfinic acid								X		
	Ammonia	X								X	X
	Amosite Asbestos	X									
	n-Amyl Acetate									X	
	Amyl alcohol									X	
	Anticoagulant rodenticides								X		X
	Arsenic Acid	X									
	Arsenic Trioxide	X									
	Arsine	X									
	Benzaldehyde								X		
	Benzene, C4-C16 alkyl derivatives								X		
	Benzene, C10-C13 alkyl derivatives								X		
	Benzene, C10-C16 alkyl derivatives								X		
	Benzene, mono C10-14alkyl derivatives								X		
	Benzene, mono C10-13 alkyl derivatives								X		
	Benzene, mono C12-14 alkyl deriviatives								X		
	Benzene, mono C14-16 alkyl derivatives								X		
	Benzyl Chloride						X		X		
	Boron								X		
	Brominated diphenylethers								X		X
	Bromine	X						X			
	Bromodichloroethane	X									
	Butachlor			X							
	1,3-Butadiene								X		
	iso-Butanal								X		
	n-Butanal								X		
	1,2,4-Butanetricarboxylic Acid, 2-phosphate								X		
	Butanols										X
	2-Butene								X		
	2-Butenedioic acid (E)-, diethyl ester								X		
	2-Butoxyethanol								X		
	2-(2-butoxyethoxy) ethanol								X		
	n-Butyl Acetate									X	
	N-Butylbenzene			X							
	1,2-Butylene glycol								X		
	t-Butyl hydroperoxide								X		
	Camphene								X		
	Carbaryl			X			X	X	X		X
	Carbofuran				X			X			
	Carbon-14	X									
	Carbon Monoxide										X
	Carbophenothion	X						X			
	Chlordecone										X
	Chlorendic acid								X		X
	Chlorendic anhydride								X		X
	Chlorinated Paraffins					X			X		X
	Chlorine	X									X
	Chloroacetic Acid								X		
	Chloroacetic Acid, Sodium Salt								X		
	1-Chlorobutane						X		X		
	(2-Chloroethyl) Ether, Bis-		X				X				
	4-Chloro-2-methylphenol						X		X		
	4-Chlorophenyl Ether		X				X				
	Chloroprene								X		
	1-Chloro-2-propanol						X		X		
	3-Chloropropene						X		X		
	Chlorothalonil						X		X		X
	Chlorotoluene	X		X			X				
	Chlorpyrifos	X						X			
	Chromic Acid	X									
	Chrysotile Asbestos	X							X		
	Coal Tar Pitch	X									
	Coal Tars	X									
	Copper, 29H,31H-Phtalocyaninato(2-)								X		
	Creosote	X									
	o-Cresol								X		X
	Cresol, Para-	X							X		X
	Cresol, Para-, Chloro-, Meta		X						X		X
	Cumene								X		
	Cyclohexanone								X		
	Cyclotrimethylenetrinitramine (Rdx)	X									
	Cypermethrin, alpha-										X
	D and C Red No. 7								X		
	Dalapon				X						
	Dcpa Mono-Acid Degradate			p							

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Dehydrolinalool								X		
	Diaminotoluenes										X
	Dibenzothiophene	X									
	(2,3-Dibromo-propyl) phosphate, Tris- and Bis-								X		X
	Di-butyl adipate								X		
	Dibutyl phosphate								X		
	Dicamba			X							
	1,2-Dichloro-3-nitrobenzene								X		
	1,4-Dichloro-2-nitrobenzene								X		
	2,4-Dichloro-1-nitrobenzene								X		
	2,4-Dichlorophenoxyacetic Acid						X				X
	4-(2,4-Dichlorophenoxy)Butyric Acid	X					X				
	Dichloroprop	X					X				
	2,4-Dichlorotoluene						X		X		
	2,6-Dichlorotoluene						X		X		
	Dicofol	X					X	X			
	1,4-Dicyanobutane								X		
	Dicyclopentadiene								X		
	Diethanolamine								X		
	Diethyl Amine									X	
	1,4-Diethylbenzene								X		
	Diethylenetriamine								X		
	Diethyl Phthalate		X								
	Diflubenzuron								X		
	2-(1,3-Dihydro-3-oxo-2H-indol-2-ylidene)-1,2-dihydro-3H-indol-3-one								X		
	Di-iso-Butyl Ketone								X		
	Dimethylaminoethanol								X		
	Dimethylarsinic Acid	X									
	Dimethyl dioctadecyl ammonium chloride								X		
	Dimethyl Formamide	X									X
	Dimethyl Phthalate		X								
	Dimethyl Sulfate										X
	Dimethyl Sulfoxide									X	
	4,6-Dinitro-O-Cresol	X	X								
	2,4-Dinitrotoluene								X		
	Dipentaerythritol								X		
	1,2-Diphenylhydrazine			p							
	Disulfoton			p							
	2,6-Di-tert-butyl phenol								X		
	Diuron			p							
	Dodecanedioic Acid								X		
	1-Dodecanol								X		
	Dodecyl benzene								X		
	Epichlorohydrin				X						X
	Eptc			p							
	Ethanol									X	
	2,2'-(1,2-Ethenediyl)bis(5-amino-)benzenesulfonic acid								X		
	2-Ethoxyethanol										
	Ethyl Acetate									X	
	Ethylbenzene								X		
	Ethylene								X		
	Ethylene Oxide										X
	Ethyl Ether	X									
	2-Ethylhexanol								X		
	4-Ethyoxyaniline								X		
	5-Ethyl-2-picoline								X		
	Fluoride	X									X
	Fonofos			p							
	Formaldehyde	X									X
	Fully Halogenated Chlorofluorocarbons						X				X
	Glutaraldehyde								X		
	Guthion	X									
	n-Heptane									X	
	Hexachlorocyclohexane	X					X				
	Hexachlorocyclohexane, Alpha-	X					X				X
	Hexachlorocyclohexane, Beta-	X					X				X
	Hexachlorocyclohexane, Delta-	X					X				
	Hexachlorocyclohexane, Gamma-	X					X				
	Hexamethylene glycol								X		
	n-Hexane									X	X
	1,6-Hexanediamine								X		
	Hydrazine	X									X
	Hydrogen Cyanide	X						X			
	Hydrogen Sulfide	X									X
	Hydroquinone								X		X

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	3-Hydroxycarbofuran										
	1,1,1-Tris-hydroxymethyl propane								X		
	2-Hydroxypropanenitrile								X		
	Isobenzan										X
	Isobutyraldehyde								X	X	
	Isophorone		X						X		X
	Isopropanol									X	
	Isopropyl Acetate									X	
	Isopropylbenzene										
	Isopropyl Ether									X	
	Isopropyltoluene										
	Kelevan										X
	L-Asorbic Acid								X		
	Limonene								X		
	Linear alkylbenzene sulfonates								X		X
	Linuron			p							
	Maleic Acid, dibutyl ester								X		
	3-Methoxyaniline								X		
	2-[2-(2-Methoxyethoxy)ethoxy]ethanol								X		
	2-Methyl-3-buten-2-ol								X		
	3-Methyl-4-nitrophenol								X		
	Melamine								X		
	Mercuric Chloride	X									
	Methanol								X	X	
	Methomyl						X	X	X		X
	2-Methyl-3-Butyn-2-ol								X		
	Methyl Cellosolve									X	
	4,4'-Methylenebis(2-Chloroaniline)	X									
	(1-Methylethenyl)benzene								X		
	Methylene butanedioic acid								X		
	Methyl Ethyl Ketone								X		X
	Methyl Formate								X		
	Methyl Mercury	X									X
	Methyl Methacrylate								X		
	2-Methyl-Phenol			p			X				
	Metolachlor			X							
	2-Methoxyethanol										X
	Metribuzin			X			X				
	Mirex						X				X
	Morpholine										X
	Mtbe			p					X		
	Mycotoxins										X
	Naled	X									
	Neopentyl glycol								X		
	Nicotonic								X		
	m-Nitroaniline								X		
	Nitrogen Dioxide	X							X		X
	4-Nitro-N-phenylaniline								X		
	2-Nitropropane										X
	o-Nitrotoluene								X		
	Nonachlor, Cis-	X									
	Nonachlor, Trans-	X									
	Ochratoxins										X
	1-Octadecanol (Stearyl)								X		
	iso-Octyl acrylate								X		
	Oxychlordane	X					X				
	Ozone	X									
	Palladium	X									
	Partially Halogenated Chlorofluorocarbons						X				X
	1,3-Pentadiene								X		
	Pentaerythritol								X		
	3-Penten-2-one, 4-methyl-mesityl oxide								X		
	n-Phenyl-1-Napthylamine								X		
	Phosgene								X		
	Phosphides										X
	Phosphine										X
	Tris(phosphonomethyl)amine								X		
	Phosphoric Acid, methylphenyl diphenyl ester								X		
	Phosphorodithioic Acid, O-Ethyl S,S-Dipro	X									
	Photochemical Oxidants										X
	Polybrominated Biphenyls	X							X		X
	Polychlorinated Biphenyls	X					X				X
	Polycyclic Aromatic Hydrocarbons	X					X		X		
	Prometon			p							
	Propachlor			X							X

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Propanal								X		
	1-Propanol										X
	2-Propanol								X		X
	Propylbenzene-N			X							
	Propylene Oxide										X
	Pyrethrum	X									
	Pyrrolizidine Alkaloids										X
	Resmethrins										X
	Sec-Butylbenzene			X							
	Sevin	X									
	Sodium lauryl sulfate								X		
	Strobane	X									
	Sulfate			X							
	Sulfur Oxides										X
	Sutan	X									
	Terbacil			p							
	Terbufos			p				X			
	Tert-Butylbenzene			X							
	6-tert-butyl-2,4-xylenol								X		
	Tetrabromo-bis-phenol A								X		X
	Tetrachlorobiphenyl	X					X				
	Tetrachlorophenol	X					X				
	2,3,4,5-Tetrachlorophenol	X					X				
	2,3,5,6-Tetrachlorophenol	X					X				
	2,3,5,6-Tetracholropyridine						X		X		
	Tetradifon										X
	1,1,2,2-Tetrafluroethane								X		
	Tetrahydrofuran								X		
	Tetramethrin										X
	4-(1,1,3,3-Tetramethybutyl)-phenol						X				
	Texanol								X		
	Thiocyanate	X									
	0-Toluidine								X		
	Toluene Diisocyanates										X
	p-Toluenesulfonamide								X		
	S,S,S-Tributyl Phosphorotrithioate	X									
	Tributyltin	X					X				X
	Trichloroacetic acid						X		X		
	1,2,3-Trichloropropane			X			X				
	Trichothecenes										X
	Tricresyl Phosphate										X
	Triethyl Amine									X	
	Tri-ethylene glycol, monoethyl ether								X		
	Triethylene tetramine								X		
	Triglycidyl Isocyanurate								X		
	1,2,4-Trimethylbenzene			X	X						
	1,3,5-Trimethylbenzene			X							
	2,3,4-Trimethyl-1,3-pentaediol ester dissobutylate								X		
	Tri-methyl phosphate								X		
	Tri-n-butyl phosphate										X
	1,3,5-Trinitrobenzene	X									
	2,4,6-Trinitrotoluene	X									
	Triphenyl phosphate										X
	Tripropolyene glycol								X		
	Undecyl benzene								X		
	Urea								X		
	Vanilin								X		
	Vinylidene Chloride										X
	White Spirit (Stoddard Solvent)								X		X
Microbiological											
	Acanthamoeba			p							
	Adenoviruses			p							
	Aeromonas Hydrophila			p							
	Astrovirus										
	Caliciviruses			p							
	Coxsackieviruses			p							
	Campylobacter Jejuni										
	Cryptosporidium Parvum										
	Cyclospora										
	Chloroform				x	x			X	X	
	Echoviruses			p							
	Entamoeba histolytica										
	Escherichia Coli O157:H7										
	Giardia Lamblia				x						

Attachment 1. Possible Contaminants of Concern

Constituent Type	Constituent	CERCLA	PP	CCL	MCL FED	MCL CA	Endocrine Disruptor	Codex	IFCS	Part 439	WHO
	Helicobacter Pylori			p							
	Hepatitus A										
	Hepatitus C										
	Hepatitus E										
	Hepatitus G										
	Legionella				x						
	Listeria										
	Microsporidia			p							
	Mycobacteriumm Avium Intracellulare			p							
	Norwalk Agent										
	Poliovirus										
	Rotavirus										
	Salmonella										
	Shigella										
	Vibrio Cholerae O139										
	Yersinaia enterocolitica										

Notes

CERCLA: 1997 CERCLA Priority List of Hazardous Substances. This list prioritizes substances most commonly found at superfund sites. The list is revised every two years to reflect additional information on hazardous substances. The majority of these compounds have toxicity profiles developed by the Agency for Toxic Substances and Disease Registry (ATSDR).
PP: Federal Priority Pollutant
CCL: Contaminant Candidate List; 40CFR Parts 141 and 142 Contaminant Monitoring Regulation for Public Water Systems; Unregulated Contaminant Monitoring List. "p" indicates the chemical was proposed but not included in the final regulation.
MCL FED: Constituents regulated under the Current Federal Drinking Water Standards
MCL CA: Constituents regulated under the Current California Drinking Water Standards
Codex: Codex Alimentarius Pesticides. Has created a list of acceptable residual levels for several pesticides for certain food commodities.
IFCS: Intergovernmental Forum on Chemical Safety. List of chemicals assessed (1994-1998).
Part 439: Pharmaceutical Manufacturing Point Source Category. Effluent limitations set by the federal government for Pharmaceutical Manufacturers.
WHO: World Health Organization Environmental Health Criteria Series, 1999.

Attachment 2: Banks Pumping Plant DWR Sampling Station Additional Data

Attachment 2. Banks Pumping Plant at California Aquaduct (all results in ug/L)

Collection Date		1,1,1,2-Tetrachloroethane		1,1,1-Trichloroethane		1,1,2,2-Tetrachloroethane		1,1,2-Trichloroethane		1,1-Dichloroethane		1,1-Dichloroethene
6/22/1995 9:55:00 AM												
7/20/1995 10:38:00 AM												
8/17/1995 9:15:00 AM												
9/14/1995 9:43:00 AM												
10/19/1995 10:30:00 AM												
11/16/1995 11:00:00 AM												
12/7/1995 11:47:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/18/1996 11:42:00 AM												
2/15/1996 11:24:00 AM												
3/14/1996 12:35:00 PM												
4/11/1996 10:26:00 AM												
5/9/1996 10:40:00 AM												
6/13/1996 12:25:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/18/1996 12:20:00 PM												
8/15/1996 9:51:00 AM												
9/12/1996 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/10/1996 9:53:00 AM												
11/14/1996 12:35:00 PM												
12/12/1996 12:45:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/7/1997 2:08:00 PM												
2/13/1997 11:20:00 AM												
3/13/1997 12:30:00 PM												
4/9/1997 10:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/13/1997 11:15:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/4/1997 9:28:00 AM												
7/2/1997 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/17/1997 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/21/1998 9:00:00 AM												
2/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/18/1998 8:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/15/1998 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/20/1998 6:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/17/1998 7:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/15/1998 7:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/19/1998 5:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/16/1998 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/21/1998 6:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/16/1998 8:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/20/1999 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
2/17/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/17/1999 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/21/1999 7:13:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/19/1999 7:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/16/1999 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/21/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/18/1999 6:35:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/15/1999 9:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/20/1999 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/17/1999 7:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/15/1999 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/19/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
2/16/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/15/2000 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/19/2000 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/17/2000 6:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/21/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/19/2000 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/16/2000 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/20/2000 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/18/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/15/2000 8:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/20/2000 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/27/2000 9:00:00 AM												
1/10/2001 8:55:48 AM												
1/10/2001 9:00:00 AM												
1/10/2001 9:05:48 AM												
1/17/2001 9:45:11 AM												
2/15/2001 11:35:00 AM												
2/15/2001 11:43:00 AM												
2/16/2001 10:55:00 AM												
2/16/2001 11:33:00 AM												
2/21/2001 8:05:16 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/21/2002 5:19:06 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/18/2002 5:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/18/2002 6:12:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:45:00 AM												
10/15/2003 7:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/19/2003 7:40:00 AM												
12/17/2003 7:20:00 AM												
12/17/2003 7:25:00 AM												
1/21/2004 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
count		50		50		50		50		50		50
# NDs		50		50		50		50		50		50
average		0.5		0.5		0.5		0.5		0.5		0.5
stand dev		0		0		0		0		0		0

Attachment 2. Banks Pump

Collection Date		1,1-Dichloropropene		1,2,3-Trichlorobenzene		1,2,3-Trichloropropane		1,2,4-Trichlorobenzene		1,2,4-Trimethylbenzene
6/22/1995 9:55:00 AM										
7/20/1995 10:38:00 AM										
8/17/1995 9:15:00 AM										
9/14/1995 9:43:00 AM										
10/19/1995 10:30:00 AM										
11/16/1995 11:00:00 AM										
12/7/1995 11:47:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/18/1996 11:42:00 AM										
2/15/1996 11:24:00 AM										
3/14/1996 12:35:00 PM										
4/11/1996 10:26:00 AM										
5/9/1996 10:40:00 AM										
6/13/1996 12:25:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/18/1996 12:20:00 PM										
8/15/1996 9:51:00 AM										
9/12/1996 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/10/1996 9:53:00 AM										
11/14/1996 12:35:00 PM										
12/12/1996 12:45:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/7/1997 2:08:00 PM										
2/13/1997 11:20:00 AM										
3/13/1997 12:30:00 PM										
4/9/1997 10:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/13/1997 11:15:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/4/1997 9:28:00 AM										
7/2/1997 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/17/1997 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/21/1998 9:00:00 AM										
2/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/18/1998 8:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/15/1998 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/20/1998 6:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/17/1998 7:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/15/1998 7:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/19/1998 5:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/16/1998 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/21/1998 6:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/16/1998 8:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/20/1999 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
2/17/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/17/1999 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/21/1999 7:13:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/19/1999 7:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/16/1999 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/21/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/18/1999 6:35:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/15/1999 9:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/20/1999 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/17/1999 7:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/15/1999 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/19/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
2/16/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/15/2000 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/19/2000 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/17/2000 6:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/21/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/19/2000 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/16/2000 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/20/2000 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/18/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/15/2000 8:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/20/2000 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/27/2000 9:00:00 AM										
1/10/2001 8:55:48 AM										
1/10/2001 9:00:00 AM										
1/10/2001 9:05:48 AM										
1/17/2001 9:45:11 AM										
2/15/2001 11:35:00 AM										
2/15/2001 11:43:00 AM										
2/16/2001 10:55:00 AM										
2/16/2001 11:33:00 AM										
2/21/2001 8:05:16 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/21/2002 5:19:06 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/18/2002 5:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/18/2002 6:12:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:45:00 AM										
10/15/2003 7:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/19/2003 7:40:00 AM										
12/17/2003 7:20:00 AM										
12/17/2003 7:25:00 AM										
1/21/2004 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5

count	50	50	50	50	50
# NDs	50	50	50	50	50
average	0.5	0.5	0.5	0.5	0.5
stand dev	0	0	0	0	0

Attachment 2. Banks Pump

Collection Date		1,2-Dibromo-3-chloropropane (DBCP)		1,2-Dibromoethane		1,2-Dichlorobenzene		1,2-Dichloroethane		1,2-Dichloropropane
6/22/1995 9:55:00 AM										
7/20/1995 10:38:00 AM										
8/17/1995 9:15:00 AM										
9/14/1995 9:43:00 AM										
10/19/1995 10:30:00 AM										
11/16/1995 11:00:00 AM										
12/7/1995 11:47:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/18/1996 11:42:00 AM										
2/15/1996 11:24:00 AM										
3/14/1996 12:35:00 PM										
4/11/1996 10:26:00 AM										
5/9/1996 10:40:00 AM										
6/13/1996 12:25:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/18/1996 12:20:00 PM										
8/15/1996 9:51:00 AM										
9/12/1996 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/10/1996 9:53:00 AM										
11/14/1996 12:35:00 PM										
12/12/1996 12:45:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/7/1997 2:08:00 PM										
2/13/1997 11:20:00 AM										
3/13/1997 12:30:00 PM										
4/9/1997 10:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/13/1997 11:15:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/4/1997 9:28:00 AM										
7/2/1997 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/17/1997 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/21/1998 9:00:00 AM										
2/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/18/1998 8:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/15/1998 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/20/1998 6:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/17/1998 7:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/15/1998 7:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/19/1998 5:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/16/1998 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/21/1998 6:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/16/1998 8:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/20/1999 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
2/17/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/17/1999 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/21/1999 7:13:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/19/1999 7:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/16/1999 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/21/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/18/1999 6:35:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/15/1999 9:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/20/1999 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/17/1999 7:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/15/1999 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
1/19/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
2/16/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
3/15/2000 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
4/19/2000 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
5/17/2000 6:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
6/21/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
7/19/2000 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/16/2000 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/20/2000 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
10/18/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/15/2000 8:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/20/2000 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/27/2000 9:00:00 AM										
1/10/2001 8:55:48 AM										
1/10/2001 9:00:00 AM										
1/10/2001 9:05:48 AM										
1/17/2001 9:45:11 AM										
2/15/2001 11:35:00 AM										
2/15/2001 11:43:00 AM										
2/16/2001 10:55:00 AM										
2/16/2001 11:33:00 AM										
2/21/2001 8:05:16 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
8/21/2002 5:19:06 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/18/2002 5:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
12/18/2002 6:12:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:45:00 AM										
10/15/2003 7:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5
11/19/2003 7:40:00 AM										
12/17/2003 7:20:00 AM										
12/17/2003 7:25:00 AM										
1/21/2004 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5

	1,2-Dibromo-3-chloropropane (DBCP)	1,2-Dibromoethane	1,2-Dichlorobenzene	1,2-Dichloroethane	1,2-Dichloropropane
count	50	50	50	50	50
# NDs	50	50	50	50	50
average	0.5	0.5	0.5	0.5	0.5
stand dev	0	0	0	0	0

Attachment 2. Banks Pump

Collection Date		1,3,5-Trimethylbenzene		1,3-Dichlorobenzene		1,3-Dichloropropane		1,4-Dichlorobenzene		1-Naphthol		2,2-Dichloropropane
6/22/1995 9:55:00 AM												
7/20/1995 10:38:00 AM												
8/17/1995 9:15:00 AM												
9/14/1995 9:43:00 AM												
10/19/1995 10:30:00 AM												
11/16/1995 11:00:00 AM												
12/7/1995 11:47:00 AM	<	0.5	<	0.5	<	0.5	<	0.5	<	4	<	0.5
1/18/1996 11:42:00 AM												
2/15/1996 11:24:00 AM												
3/14/1996 12:35:00 PM									<	4		
4/11/1996 10:26:00 AM												
5/9/1996 10:40:00 AM												
6/13/1996 12:25:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	4	<	0.5
7/18/1996 12:20:00 PM												
8/15/1996 9:51:00 AM												
9/12/1996 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	4	<	0.5
10/10/1996 9:53:00 AM												
11/14/1996 12:35:00 PM												
12/12/1996 12:45:00 PM	<	0.5	<	0.5	<	0.5	<	0.5	<	4	<	0.5
1/7/1997 2:08:00 PM												
2/13/1997 11:20:00 AM												
3/13/1997 12:30:00 PM												
4/9/1997 10:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
5/13/1997 11:15:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
6/4/1997 9:28:00 AM												
7/2/1997 12:30:00 PM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
12/17/1997 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
1/21/1998 9:00:00 AM												
2/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
3/18/1998 8:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
4/15/1998 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
5/20/1998 6:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
6/17/1998 7:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
7/15/1998 7:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
8/19/1998 5:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
9/16/1998 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
10/21/1998 6:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
11/18/1998 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
12/16/1998 8:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
1/20/1999 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
2/17/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
3/17/1999 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
4/21/1999 7:13:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
5/19/1999 7:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
6/16/1999 8:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
7/21/1999 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
8/18/1999 6:35:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
9/15/1999 9:55:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
10/20/1999 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
11/17/1999 7:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
12/15/1999 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
1/19/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
2/16/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
3/15/2000 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
4/19/2000 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
5/17/2000 6:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
6/21/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
7/19/2000 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
8/16/2000 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
9/20/2000 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
10/18/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
11/15/2000 8:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
12/20/2000 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
12/27/2000 9:00:00 AM												
1/10/2001 8:55:48 AM												
1/10/2001 9:00:00 AM												
1/10/2001 9:05:48 AM												
1/17/2001 9:45:11 AM												
2/15/2001 11:35:00 AM												
2/15/2001 11:43:00 AM												
2/16/2001 10:55:00 AM												
2/16/2001 11:33:00 AM												
2/21/2001 8:05:16 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
8/21/2002 5:19:06 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
9/18/2002 5:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
12/18/2002 6:12:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
9/17/2003 7:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
9/17/2003 7:45:00 AM												
10/15/2003 7:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
11/19/2003 7:40:00 AM												
12/17/2003 7:20:00 AM												
12/17/2003 7:25:00 AM												
1/21/2004 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5			<	0.5
count		50		50		50		50		5		50
# NDs		50		50		50		50		5		50
average		0.5		0.5		0.5		0.5		4		0.5
stand dev		0		0		0		0		0		0

Attachment 2. Banks Pum

Collection Date		2,3,7,8-Tetrachlorodibenzo-p-dioxin		2,4,5-T		2,4,5-TP (Silvex)		2,4-D		2,4-DB		2-Chlorotoluene		3-Hydroxycarbofuran		4-Chlorotoluene
6/22/1995 9:55:00 AM																
7/20/1995 10:38:00 AM																
8/17/1995 9:15:00 AM																
9/14/1995 9:43:00 AM																
10/19/1995 10:30:00 AM																
11/16/1995 11:00:00 AM																
12/7/1995 11:47:00 AM	<	3.8	<	0.2	<	0.2	<	0.1			<	0.5	<	2	<	0.5
1/18/1996 11:42:00 AM																
2/15/1996 11:24:00 AM																
3/14/1996 12:35:00 PM	<	2.1	<	0.2	<	0.2	<	0.1					<	2		
4/11/1996 10:26:00 AM																
5/9/1996 10:40:00 AM																
6/13/1996 12:25:00 PM	<	2.5	<	0.2	<	0.2	<	0.1			<	0.5	<	2	<	0.5
7/18/1996 12:20:00 PM																
8/15/1996 9:51:00 AM																
9/12/1996 12:30:00 PM			<	0.2	<	0.2	<	0.1			<	0.5	<	2	<	0.5
10/10/1996 9:53:00 AM																
11/14/1996 12:35:00 PM																
12/12/1996 12:45:00 PM	<	2	<	0.2	<	0.2	<	0.1			<	0.5	<	2	<	0.5
1/7/1997 2:08:00 PM																
2/13/1997 11:20:00 AM																
3/13/1997 12:30:00 PM																
4/9/1997 10:50:00 AM											<	0.5			<	0.5
5/13/1997 11:15:00 AM											<	0.5			<	0.5
6/4/1997 9:28:00 AM																
7/2/1997 12:30:00 PM											<	0.5			<	0.5
12/17/1997 9:50:00 AM											<	0.5			<	0.5
1/21/1998 9:00:00 AM																
2/18/1998 8:20:00 AM											<	0.5			<	0.5
3/18/1998 8:50:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
4/15/1998 6:30:00 AM											<	0.5			<	0.5
5/20/1998 6:00:00 AM											<	0.5			<	0.5
6/17/1998 7:05:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
7/15/1998 7:45:00 AM											<	0.5			<	0.5
8/19/1998 5:50:00 AM											<	0.5			<	0.5
9/16/1998 8:00:00 AM			<	0.1	<	0.1		0.7	<	0.1	<	0.5	<	2	<	0.5
10/21/1998 6:25:00 AM											<	0.5			<	0.5
11/18/1998 8:20:00 AM											<	0.5			<	0.5
12/16/1998 8:55:00 AM											<	0.5			<	0.5
1/20/1999 8:25:00 AM											<	0.5			<	0.5
2/17/1999 7:30:00 AM											<	0.5			<	0.5
3/17/1999 8:40:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
4/21/1999 7:13:00 AM											<	0.5			<	0.5
5/19/1999 7:20:00 AM											<	0.5			<	0.5
6/16/1999 8:00:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
7/21/1999 7:30:00 AM											<	0.5			<	0.5
8/18/1999 6:35:00 AM											<	0.5			<	0.5
9/15/1999 9:55:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
10/20/1999 6:45:00 AM											<	0.5			<	0.5
11/17/1999 7:25:00 AM											<	0.5			<	0.5
12/15/1999 6:50:00 AM											<	0.5			<	0.5
1/19/2000 8:20:00 AM											<	0.5			<	0.5
2/16/2000 8:20:00 AM											<	0.5			<	0.5
3/15/2000 8:25:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
4/19/2000 6:30:00 AM											<	0.5			<	0.5
5/17/2000 6:40:00 AM											<	0.5			<	0.5
6/21/2000 6:50:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
7/19/2000 8:40:00 AM											<	0.5			<	0.5
8/16/2000 6:45:00 AM											<	0.5			<	0.5
9/20/2000 7:30:00 AM											<	0.5			<	0.5
10/18/2000 6:50:00 AM											<	0.5			<	0.5
11/15/2000 8:05:00 AM											<	0.5			<	0.5
12/20/2000 9:50:00 AM											<	0.5			<	0.5
12/27/2000 9:00:00 AM																
1/10/2001 8:55:48 AM																
1/10/2001 9:00:00 AM																
1/10/2001 9:05:48 AM																
1/17/2001 9:45:11 AM																
2/15/2001 11:35:00 AM																
2/15/2001 11:43:00 AM																
2/16/2001 10:55:00 AM																
2/16/2001 11:33:00 AM																
2/21/2001 8:05:16 AM											<	0.5			<	0.5
8/21/2002 5:19:06 AM											<	0.5			<	0.5
9/18/2002 5:00:00 AM			<	0.1	<	0.1		0.2	<	0.1	<	0.5			<	0.5
12/18/2002 6:12:00 AM											<	0.5			<	0.5
9/17/2003 7:40:00 AM			<	0.1	<	0.1	<	0.1	<	0.1	<	0.5	<	2	<	0.5
9/17/2003 7:45:00 AM																
10/15/2003 7:50:00 AM											<	0.5			<	0.5
11/19/2003 7:40:00 AM																
12/17/2003 7:20:00 AM																
12/17/2003 7:25:00 AM																
1/21/2004 8:20:00 AM											<	0.5			<	0.5
count		4		15		15		15		10		50		14		50
# NDs		4		15		15		13		10		50		14		50
average		2.6		0.13		0.13		0.15		0.1		0.5		2		0.5
stand dev		0.83		0.05		0.05		0.16		0		0		0		0

Attachment 2. Banks Pump

Collection Date		4-Isopropyltoluene		Acifluorfen		Alachlor		Aldicarb		Aldicarb sulfone		Aldicarb sulfoxide		Aldrin		Aminomethylphosphonic Acid (AMPA)
6/22/1995 9:55:00 AM																
7/20/1995 10:38:00 AM																
8/17/1995 9:15:00 AM																
9/14/1995 9:43:00 AM																
10/19/1995 10:30:00 AM																
11/16/1995 11:00:00 AM																
12/7/1995 11:47:00 AM	<	0.5	<	0.1	<	1	<	2	<	2	<	2	<	0.07	<	100
1/18/1996 11:42:00 AM																
2/15/1996 11:24:00 AM																
3/14/1996 12:35:00 PM			<	0.1	<	1	<	2	<	2	<	2	<	0.07	<	100
4/11/1996 10:26:00 AM																
5/9/1996 10:40:00 AM																
6/13/1996 12:25:00 PM	<	0.5	<	0.1	<	1	<	2	<	2	<	2	<	0.07	<	100
7/18/1996 12:20:00 PM																
8/15/1996 9:51:00 AM																
9/12/1996 12:30:00 PM	<	0.5	<	0.1	<	1	<	2	<	2	<	2	<	0.07	<	100
10/10/1996 9:53:00 AM																
11/14/1996 12:35:00 PM																
12/12/1996 12:45:00 PM	<	0.5	<	0.1	<	1	<	2	<	2	<	2	<	0.07	<	100
1/7/1997 2:08:00 PM																
2/13/1997 11:20:00 AM																
3/13/1997 12:30:00 PM																
4/9/1997 10:50:00 AM	<	0.5														
5/13/1997 11:15:00 AM	<	0.5														
6/4/1997 9:28:00 AM																
7/2/1997 12:30:00 PM	<	0.5														
12/17/1997 9:50:00 AM	<	0.5														
1/21/1998 9:00:00 AM																
2/18/1998 8:20:00 AM	<	0.5														
3/18/1998 8:50:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
4/15/1998 6:30:00 AM	<	0.5														
5/20/1998 6:00:00 AM	<	0.5														
6/17/1998 7:05:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
7/15/1998 7:45:00 AM	<	0.5														
8/19/1998 5:50:00 AM	<	0.5														
9/16/1998 8:00:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
10/21/1998 6:25:00 AM	<	0.5														
11/18/1998 8:20:00 AM	<	0.5														
12/16/1998 8:55:00 AM	<	0.5														
1/20/1999 8:25:00 AM	<	0.5														
2/17/1999 7:30:00 AM	<	0.5														
3/17/1999 8:40:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
4/21/1999 7:13:00 AM	<	0.5														
5/19/1999 7:20:00 AM	<	0.5														
6/16/1999 8:00:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
7/21/1999 7:30:00 AM	<	0.5														
8/18/1999 6:35:00 AM	<	0.5														
9/15/1999 9:55:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
10/20/1999 6:45:00 AM	<	0.5														
11/17/1999 7:25:00 AM	<	0.5														
12/15/1999 6:50:00 AM	<	0.5														
1/19/2000 8:20:00 AM	<	0.5														
2/16/2000 8:20:00 AM	<	0.5														
3/15/2000 8:25:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
4/19/2000 6:30:00 AM	<	0.5														
5/17/2000 6:40:00 AM	<	0.5														
6/21/2000 6:50:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	100
7/19/2000 8:40:00 AM	<	0.5														
8/16/2000 6:45:00 AM	<	0.5														
9/20/2000 7:30:00 AM	<	0.5														
10/18/2000 6:50:00 AM	<	0.5														
11/15/2000 8:05:00 AM	<	0.5														
12/20/2000 9:50:00 AM	<	0.5														
12/27/2000 9:00:00 AM																
1/10/2001 8:55:48 AM																
1/10/2001 9:00:00 AM																
1/10/2001 9:05:48 AM																
1/17/2001 9:45:11 AM																
2/15/2001 11:35:00 AM																
2/15/2001 11:43:00 AM																
2/16/2001 10:55:00 AM																
2/16/2001 11:33:00 AM																
2/21/2001 8:05:16 AM	<	0.5														
8/21/2002 5:19:06 AM	<	0.5														
9/18/2002 5:00:00 AM	<	0.5			<	0.05							<	0.01		
12/18/2002 6:12:00 AM	<	0.5														
9/17/2003 7:40:00 AM	<	0.5			<	0.05	<	2	<	2	<	2	<	0.01	<	25
9/17/2003 7:45:00 AM																
10/15/2003 7:50:00 AM	<	0.5														
11/19/2003 7:40:00 AM																
12/17/2003 7:20:00 AM																
12/17/2003 7:25:00 AM																
1/21/2004 8:20:00 AM	<	0.5														
count		50		5		15		14		14		14		15		14
# NDs		50		5		15		14		14		14		15		14
average		0.5		0.1		0.37		2		2		2		0.03		94.6
stand dev		0		0		0.46		0		0		0		0.03		20.0

Attachment 2. Banks Pump

Collection Date	Asbestos, Chrysotile	Atrazine	Azinphos methyl (Guthion)	Benfluralin	Bentazon	Benzene	Benzo(a)pyrene	BHC-alpha	BHC-beta
6/22/1995 9:55:00 AM						< 0.5			
7/20/1995 10:38:00 AM									
8/17/1995 9:15:00 AM									
9/14/1995 9:43:00 AM									
10/19/1995 10:30:00 AM									
11/16/1995 11:00:00 AM									
12/7/1995 11:47:00 AM		< 1			< 2	< 0.5	< 0.1		
1/18/1996 11:42:00 AM									
2/15/1996 11:24:00 AM									
3/14/1996 12:35:00 PM		< 1			< 2		< 0.1		
4/11/1996 10:26:00 AM									
5/9/1996 10:40:00 AM									
6/13/1996 12:25:00 PM		< 1			< 2	< 0.5	< 0.1		
7/18/1996 12:20:00 PM									
8/15/1996 9:51:00 AM									
9/12/1996 12:30:00 PM		< 1			< 2	< 0.5	< 0.1		
10/10/1996 9:53:00 AM									
11/14/1996 12:35:00 PM									
12/12/1996 12:45:00 PM		< 1			< 2	< 0.5	< 0.1		
1/7/1997 2:08:00 PM									
2/13/1997 11:20:00 AM									
3/13/1997 12:30:00 PM									
4/9/1997 10:50:00 AM						< 0.5			
5/13/1997 11:15:00 AM						< 0.5			
6/4/1997 9:28:00 AM									
7/2/1997 12:30:00 PM						< 0.5			
12/17/1997 9:50:00 AM						< 0.5			
1/21/1998 9:00:00 AM									
2/18/1998 8:20:00 AM						< 0.5			
3/18/1998 8:50:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
4/15/1998 6:30:00 AM						< 0.5			
5/20/1998 6:00:00 AM						< 0.5			
6/17/1998 7:05:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
7/15/1998 7:45:00 AM						< 0.5			
8/19/1998 5:50:00 AM						< 0.5			
9/16/1998 8:00:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
10/21/1998 6:25:00 AM						< 0.5			
11/18/1998 8:20:00 AM						< 0.5			
12/16/1998 8:55:00 AM						< 0.5			
1/20/1999 8:25:00 AM						< 0.5			
2/17/1999 7:30:00 AM						< 0.5			
3/17/1999 8:40:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
4/21/1999 7:13:00 AM						< 0.5			
5/19/1999 7:20:00 AM						< 0.5			
6/16/1999 8:00:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
7/21/1999 7:30:00 AM						< 0.5			
8/18/1999 6:35:00 AM						< 0.5			
9/15/1999 9:55:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
10/20/1999 6:45:00 AM						< 0.5			
11/17/1999 7:25:00 AM						< 0.5			
12/15/1999 6:50:00 AM						< 0.5			
1/19/2000 8:20:00 AM						< 0.5			
2/16/2000 8:20:00 AM						< 0.5			
3/15/2000 8:25:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
4/19/2000 6:30:00 AM						< 0.5			
5/17/2000 6:40:00 AM						< 0.5			
6/21/2000 6:50:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
7/19/2000 8:40:00 AM						< 0.5			
8/16/2000 6:45:00 AM						< 0.5			
9/20/2000 7:30:00 AM						< 0.5			
10/18/2000 6:50:00 AM						< 0.5			
11/15/2000 8:05:00 AM						< 0.5			
12/20/2000 9:50:00 AM						< 0.5			
12/27/2000 9:00:00 AM									
1/10/2001 8:55:48 AM									
1/10/2001 9:00:00 AM									
1/10/2001 9:05:48 AM									
1/17/2001 9:45:11 AM									
2/15/2001 11:35:00 AM									
2/15/2001 11:43:00 AM									
2/16/2001 10:55:00 AM									
2/16/2001 11:33:00 AM									
2/21/2001 8:05:16 AM						< 0.5			
8/21/2002 5:19:06 AM						< 0.5			
9/18/2002 5:00:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
12/18/2002 6:12:00 AM						< 0.5			
9/17/2003 7:40:00 AM		< 0.02	< 0.05	< 0.01		< 0.5		< 0.01	< 0.01
9/17/2003 7:45:00 AM									
10/15/2003 7:50:00 AM						< 0.5			
11/19/2003 7:40:00 AM									
12/17/2003 7:20:00 AM									
12/17/2003 7:25:00 AM									
1/21/2004 8:20:00 AM						< 0.5			
count		15	10	10	5	51	5	10	10
# NDs		15	10	10	5	51	5	10	10
average		0.35	0.05	0.01	2	0.5	0.1	0.01	0.01
stand dev		0.48	0	0	0	0	0	0	0

Attachment 2. Banks Pump

Collection Date		BHC-delta		BHC-gamma (Lindane)		Bis(2-ethylhexyl) adipate		bis(2-Ethylhexyl) phthalate		Bromacil		Bromobenzene
6/22/1995 9:55:00 AM												
7/20/1995 10:38:00 AM												
8/17/1995 9:15:00 AM												
9/14/1995 9:43:00 AM												
10/19/1995 10:30:00 AM												
11/16/1995 11:00:00 AM												
12/7/1995 11:47:00 AM			<	0.04	<	3	<	3	<	10	<	0.5
1/18/1996 11:42:00 AM												
2/15/1996 11:24:00 AM												
3/14/1996 12:35:00 PM			<	0.04	<	3	<	3	<	10		
4/11/1996 10:26:00 AM												
5/9/1996 10:40:00 AM												
6/13/1996 12:25:00 PM			<	0.04	<	3	<	3	<	10	<	0.5
7/18/1996 12:20:00 PM												
8/15/1996 9:51:00 AM												
9/12/1996 12:30:00 PM			<	0.2	<	3	<	3	<	10	<	0.5
10/10/1996 9:53:00 AM												
11/14/1996 12:35:00 PM												
12/12/1996 12:45:00 PM			<	0.2	<	3	<	3	<	10	<	0.5
1/7/1997 2:08:00 PM												
2/13/1997 11:20:00 AM												
3/13/1997 12:30:00 PM												
4/9/1997 10:50:00 AM											<	0.5
5/13/1997 11:15:00 AM											<	0.5
6/4/1997 9:28:00 AM												
7/2/1997 12:30:00 PM											<	0.5
12/17/1997 9:50:00 AM											<	0.5
1/21/1998 9:00:00 AM												
2/18/1998 8:20:00 AM											<	0.5
3/18/1998 8:50:00 AM	<	0.01	<	0.01					<	1	<	0.5
4/15/1998 6:30:00 AM											<	0.5
5/20/1998 6:00:00 AM											<	0.5
6/17/1998 7:05:00 AM	<	0.01	<	0.01					<	1	<	0.5
7/15/1998 7:45:00 AM											<	0.5
8/19/1998 5:50:00 AM											<	0.5
9/16/1998 8:00:00 AM	<	0.01	<	0.01					<	1	<	0.5
10/21/1998 6:25:00 AM											<	0.5
11/18/1998 8:20:00 AM											<	0.5
12/16/1998 8:55:00 AM											<	0.5
1/20/1999 8:25:00 AM											<	0.5
2/17/1999 7:30:00 AM											<	0.5
3/17/1999 8:40:00 AM	<	0.01	<	0.01					<	1	<	0.5
4/21/1999 7:13:00 AM											<	0.5
5/19/1999 7:20:00 AM											<	0.5
6/16/1999 8:00:00 AM	<	0.01	<	0.01					<	1	<	0.5
7/21/1999 7:30:00 AM											<	0.5
8/18/1999 6:35:00 AM											<	0.5
9/15/1999 9:55:00 AM	<	0.01	<	0.01					<	1	<	0.5
10/20/1999 6:45:00 AM											<	0.5
11/17/1999 7:25:00 AM											<	0.5
12/15/1999 6:50:00 AM											<	0.5
1/19/2000 8:20:00 AM											<	0.5
2/16/2000 8:20:00 AM											<	0.5
3/15/2000 8:25:00 AM	<	0.01	<	0.01					<	1	<	0.5
4/19/2000 6:30:00 AM											<	0.5
5/17/2000 6:40:00 AM											<	0.5
6/21/2000 6:50:00 AM	<	0.01	<	0.01					<	1	<	0.5
7/19/2000 8:40:00 AM											<	0.5
8/16/2000 6:45:00 AM											<	0.5
9/20/2000 7:30:00 AM											<	0.5
10/18/2000 6:50:00 AM											<	0.5
11/15/2000 8:05:00 AM											<	0.5
12/20/2000 9:50:00 AM											<	0.5
12/27/2000 9:00:00 AM												
1/10/2001 8:55:48 AM												
1/10/2001 9:00:00 AM												
1/10/2001 9:05:48 AM												
1/17/2001 9:45:11 AM												
2/15/2001 11:35:00 AM												
2/15/2001 11:43:00 AM												
2/16/2001 10:55:00 AM												
2/16/2001 11:33:00 AM												
2/21/2001 8:05:16 AM											<	0.5
8/21/2002 5:19:06 AM											<	0.5
9/18/2002 5:00:00 AM	<	0.01	<	0.01					<	1	<	0.5
12/18/2002 6:12:00 AM											<	0.5
9/17/2003 7:40:00 AM	<	0.01	<	0.01					<	0.1	<	0.5
9/17/2003 7:45:00 AM												
10/15/2003 7:50:00 AM											<	0.5
11/19/2003 7:40:00 AM												
12/17/2003 7:20:00 AM												
12/17/2003 7:25:00 AM												
1/21/2004 8:20:00 AM											<	0.5
count		10		15		5		5		15		50
# NDs		10		15		5		5		15		50
average		0.01		0.041		3		3		3.94		0.5
stand dev		0		0.07		0		0		4.44		0

Attachment 2. Banks Pump

Collection Date	Bromochloroacetic Acid (BCAA)	Bromochloroacetonitrile	Bromochloromethane	Bromomethane	Butachlor	Captan	Carbaryl	Carbofuran
6/22/1995 9:55:00 AM								
7/20/1995 10:38:00 AM								
8/17/1995 9:15:00 AM								
9/14/1995 9:43:00 AM								
10/19/1995 10:30:00 AM								
11/16/1995 11:00:00 AM								
12/7/1995 11:47:00 AM		< 0.5	< 0.5	< 0.5	< 0.38		< 2	< 2
1/18/1996 11:42:00 AM								
2/15/1996 11:24:00 AM								
3/14/1996 12:35:00 PM		< 0.5			< 0.38		< 2	< 2
4/11/1996 10:26:00 AM	25							
5/9/1996 10:40:00 AM	17							
6/13/1996 12:25:00 PM	9.5	< 0.5	< 0.5	< 0.5	< 0.38		< 2	< 2
7/18/1996 12:20:00 PM	6.1							
8/15/1996 9:51:00 AM	16							
9/12/1996 12:30:00 PM	9.5	< 0.5	< 0.5	< 0.5	< 0.38		< 2	< 2
10/10/1996 9:53:00 AM	38							
11/14/1996 12:35:00 PM	17							
12/12/1996 12:45:00 PM	45	< 0.5	< 0.5	< 0.5	< 0.38		< 2	< 2
1/7/1997 2:08:00 PM	8							
2/13/1997 11:20:00 AM	8							
3/13/1997 12:30:00 PM	14							
4/9/1997 10:50:00 AM	27		< 0.5	< 0.5				
5/13/1997 11:15:00 AM	17		< 0.5	< 0.5				
6/4/1997 9:28:00 AM	15							
7/2/1997 12:30:00 PM	11		< 0.5	< 0.5				
12/17/1997 9:50:00 AM			< 0.5	< 0.5				
1/21/1998 9:00:00 AM								
2/18/1998 8:20:00 AM	30		< 0.5	< 0.5				
3/18/1998 8:50:00 AM	26		< 0.5	< 0.5		< 0.02	< 2	< 2
4/15/1998 6:30:00 AM	38		< 0.5	< 0.5				
5/20/1998 6:00:00 AM	26		< 0.5	< 0.5				
6/17/1998 7:05:00 AM	13		< 0.5	< 0.5		< 0.02	< 2	< 2
7/15/1998 7:45:00 AM	14		< 0.5	< 0.5				
8/19/1998 5:50:00 AM	15		< 0.5	< 0.5				
9/16/1998 8:00:00 AM	17		< 0.5	< 0.5		< 0.02	< 2	< 2
10/21/1998 6:25:00 AM	12		< 0.5	< 0.5				
11/18/1998 8:20:00 AM	15		< 0.5	< 0.5				
12/16/1998 8:55:00 AM	25		< 0.5	< 0.5				
1/20/1999 8:25:00 AM	23		< 0.5	< 0.5				
2/17/1999 7:30:00 AM	36		< 0.5	< 0.5				
3/17/1999 8:40:00 AM	10		< 0.5	< 0.5		< 0.02	< 2	< 2
4/21/1999 7:13:00 AM	22		< 0.5	< 0.5				
5/19/1999 7:20:00 AM	17		< 0.5	< 0.5				
6/16/1999 8:00:00 AM	20		< 0.5	< 0.5		< 0.02	< 2	< 2
7/21/1999 7:30:00 AM	11		< 0.5	< 0.5				
8/18/1999 6:35:00 AM			< 0.5	< 0.5				
9/15/1999 9:55:00 AM			< 0.5	< 0.5		< 0.02	< 2	< 2
10/20/1999 6:45:00 AM			< 0.5	< 0.5				
11/17/1999 7:25:00 AM			< 0.5	< 0.5				
12/15/1999 6:50:00 AM			< 0.5	< 0.5				
1/19/2000 8:20:00 AM			< 0.5	< 0.5				
2/16/2000 8:20:00 AM			< 0.5	< 0.5				
3/15/2000 8:25:00 AM			< 0.5	< 0.5		< 0.02	< 2	< 2
4/19/2000 6:30:00 AM			< 0.5	< 0.5				
5/17/2000 6:40:00 AM			< 0.5	< 0.5				
6/21/2000 6:50:00 AM			< 0.5	< 0.5		< 0.02	< 2	< 2
7/19/2000 8:40:00 AM			< 0.5	< 0.5				
8/16/2000 6:45:00 AM			< 0.5	< 0.5				
9/20/2000 7:30:00 AM			< 0.5	< 0.5				
10/18/2000 6:50:00 AM			< 0.5	< 0.5				
11/15/2000 8:05:00 AM			< 0.5	< 0.5				
12/20/2000 9:50:00 AM			< 0.5	< 0.5				
12/27/2000 9:00:00 AM								
1/10/2001 8:55:48 AM								
1/10/2001 9:00:00 AM								
1/10/2001 9:05:48 AM								
1/17/2001 9:45:11 AM								
2/15/2001 11:35:00 AM								
2/15/2001 11:43:00 AM								
2/16/2001 10:55:00 AM								
2/16/2001 11:33:00 AM								
2/21/2001 8:05:16 AM			< 0.5	< 0.5				
8/21/2002 5:19:06 AM			< 0.5	< 0.5				
9/18/2002 5:00:00 AM			< 0.5	< 0.5		< 0.02		
12/18/2002 6:12:00 AM			< 0.5	< 0.5				
9/17/2003 7:40:00 AM			< 0.5	< 0.5		< 0.05	< 2	< 2
9/17/2003 7:45:00 AM								
10/15/2003 7:50:00 AM			< 0.5	< 0.5				
11/19/2003 7:40:00 AM								
12/17/2003 7:20:00 AM								
12/17/2003 7:25:00 AM								
1/21/2004 8:20:00 AM			< 0.5	< 0.5				
count	34	5	50	50	5	10	14	14
# NDs	0	5	50	50	5	10	14	14
average	19.2	0.5	0.5	0.5	0.38	0.023	2	2
stand dev	9.66	0	0	0	0	0.01	0	0

Attachment 2. Banks Pump

Collection Date		Carbon tetrachloride		Carbophenothion (Trithion)		Chlordane		Chlorobenzene		Chloroethane		Chloromethane		Chloropicrin		Chlorothalonil
6/22/1995 9:55:00 AM																
7/20/1995 10:38:00 AM																
8/17/1995 9:15:00 AM																
9/14/1995 9:43:00 AM																
10/19/1995 10:30:00 AM																
11/16/1995 11:00:00 AM																
12/7/1995 11:47:00 AM	<	0.5			<	0.1	<	0.5	<	0.5	<	0.5	<	2	<	5
1/18/1996 11:42:00 AM																
2/15/1996 11:24:00 AM																
3/14/1996 12:35:00 PM					<	0.1							<	2	<	5
4/11/1996 10:26:00 AM																
5/9/1996 10:40:00 AM																
6/13/1996 12:25:00 PM	<	0.5			<	0.1	<	0.5	<	0.5	<	0.5	<	2	<	5
7/18/1996 12:20:00 PM																
8/15/1996 9:51:00 AM																
9/12/1996 12:30:00 PM	<	0.5			<	0.1	<	0.5	<	0.5	<	0.5	<	2	<	5
10/10/1996 9:53:00 AM																
11/14/1996 12:35:00 PM																
12/12/1996 12:45:00 PM	<	0.5			<	0.1	<	0.5	<	0.5	<	0.5	<	2	<	5
1/7/1997 2:08:00 PM																
2/13/1997 11:20:00 AM																
3/13/1997 12:30:00 PM																
4/9/1997 10:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
5/13/1997 11:15:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
6/4/1997 9:28:00 AM																
7/2/1997 12:30:00 PM	<	0.5					<	0.5	<	0.5	<	0.5				
12/17/1997 9:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
1/21/1998 9:00:00 AM																
2/18/1998 8:20:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
3/18/1998 8:50:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
4/15/1998 6:30:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
5/20/1998 6:00:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
6/17/1998 7:05:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
7/15/1998 7:45:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
8/19/1998 5:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
9/16/1998 8:00:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
10/21/1998 6:25:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
11/18/1998 8:20:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
12/16/1998 8:55:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
1/20/1999 8:25:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
2/17/1999 7:30:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
3/17/1999 8:40:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
4/21/1999 7:13:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
5/19/1999 7:20:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
6/16/1999 8:00:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
7/21/1999 7:30:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
8/18/1999 6:35:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
9/15/1999 9:55:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
10/20/1999 6:45:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
11/17/1999 7:25:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
12/15/1999 6:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
1/19/2000 8:20:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
2/16/2000 8:20:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
3/15/2000 8:25:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
4/19/2000 6:30:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
5/17/2000 6:40:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
6/21/2000 6:50:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
7/19/2000 8:40:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
8/16/2000 6:45:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
9/20/2000 7:30:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
10/18/2000 6:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
11/15/2000 8:05:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
12/20/2000 9:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
12/27/2000 9:00:00 AM																
1/10/2001 8:55:48 AM																
1/10/2001 9:00:00 AM																
1/10/2001 9:05:48 AM																
1/17/2001 9:45:11 AM																
2/15/2001 11:35:00 AM																
2/15/2001 11:43:00 AM																
2/16/2001 10:55:00 AM																
2/16/2001 11:33:00 AM																
2/21/2001 8:05:16 AM	<	0.5					<	0.5	<	0.5	<	0.5				
8/21/2002 5:19:06 AM	<	0.5					<	0.5	<	0.5	<	0.5				
9/18/2002 5:00:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
12/18/2002 6:12:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
9/17/2003 7:40:00 AM	<	0.5	<	0.02	<	0.05	<	0.5	<	0.5	<	0.5			<	0.01
9/17/2003 7:45:00 AM																
10/15/2003 7:50:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
11/19/2003 7:40:00 AM																
12/17/2003 7:20:00 AM																
12/17/2003 7:25:00 AM																
1/21/2004 8:20:00 AM	<	0.5					<	0.5	<	0.5	<	0.5				
count		50		10		15		50		50		50		5		15
# NDs		50		10		15		50		50		50		5		15
average		0.5		0.02		0.067		0.5		0.5		0.5		2		1.67
stand dev		0		0		0.02		0		0		0		0		2.43

Attachment 2. Banks Pump

Collection Date		Chlorpropham		Chlorpyrifos		cis-1,2-Dichloroethene		cis-1,3-Dichloropropene		Cyanazine		Dacthal (DCPA)		Dalapon
6/22/1995 9:55:00 AM														
7/20/1995 10:38:00 AM														
8/17/1995 9:15:00 AM														
9/14/1995 9:43:00 AM														
10/19/1995 10:30:00 AM														
11/16/1995 11:00:00 AM														
12/7/1995 11:47:00 AM					<	0.5	<	0.5					<	1
1/18/1996 11:42:00 AM														
2/15/1996 11:24:00 AM														
3/14/1996 12:35:00 PM													<	1
4/11/1996 10:26:00 AM														
5/9/1996 10:40:00 AM														
6/13/1996 12:25:00 PM					<	0.5	<	0.5					<	1
7/18/1996 12:20:00 PM														
8/15/1996 9:51:00 AM														
9/12/1996 12:30:00 PM					<	0.5	<	0.5					<	1
10/10/1996 9:53:00 AM														
11/14/1996 12:35:00 PM														
12/12/1996 12:45:00 PM					<	0.5	<	0.5						2.3
1/7/1997 2:08:00 PM														
2/13/1997 11:20:00 AM														
3/13/1997 12:30:00 PM														
4/9/1997 10:50:00 AM					<	0.5	<	0.5						
5/13/1997 11:15:00 AM					<	0.5	<	0.5						
6/4/1997 9:28:00 AM														
7/2/1997 12:30:00 PM					<	0.5	<	0.5						
12/17/1997 9:50:00 AM					<	0.5	<	0.5						
1/21/1998 9:00:00 AM														
2/18/1998 8:20:00 AM					<	0.5	<	0.5						
3/18/1998 8:50:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
4/15/1998 6:30:00 AM					<	0.5	<	0.5						
5/20/1998 6:00:00 AM					<	0.5	<	0.5						
6/17/1998 7:05:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
7/15/1998 7:45:00 AM					<	0.5	<	0.5						
8/19/1998 5:50:00 AM					<	0.5	<	0.5						
9/16/1998 8:00:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
10/21/1998 6:25:00 AM					<	0.5	<	0.5						
11/18/1998 8:20:00 AM					<	0.5	<	0.5						
12/16/1998 8:55:00 AM					<	0.5	<	0.5						
1/20/1999 8:25:00 AM					<	0.5	<	0.5						
2/17/1999 7:30:00 AM					<	0.5	<	0.5						
3/17/1999 8:40:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
4/21/1999 7:13:00 AM					<	0.5	<	0.5						
5/19/1999 7:20:00 AM					<	0.5	<	0.5						
6/16/1999 8:00:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
7/21/1999 7:30:00 AM					<	0.5	<	0.5						
8/18/1999 6:35:00 AM					<	0.5	<	0.5						
9/15/1999 9:55:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
10/20/1999 6:45:00 AM					<	0.5	<	0.5						
11/17/1999 7:25:00 AM					<	0.5	<	0.5						
12/15/1999 6:50:00 AM					<	0.5	<	0.5						
1/19/2000 8:20:00 AM					<	0.5	<	0.5						
2/16/2000 8:20:00 AM					<	0.5	<	0.5						
3/15/2000 8:25:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
4/19/2000 6:30:00 AM					<	0.5	<	0.5						
5/17/2000 6:40:00 AM					<	0.5	<	0.5						
6/21/2000 6:50:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
7/19/2000 8:40:00 AM					<	0.5	<	0.5						
8/16/2000 6:45:00 AM					<	0.5	<	0.5						
9/20/2000 7:30:00 AM					<	0.5	<	0.5						
10/18/2000 6:50:00 AM					<	0.5	<	0.5						
11/15/2000 8:05:00 AM					<	0.5	<	0.5						
12/20/2000 9:50:00 AM					<	0.5	<	0.5						
12/27/2000 9:00:00 AM														
1/10/2001 8:55:48 AM														
1/10/2001 9:00:00 AM														
1/10/2001 9:05:48 AM														
1/17/2001 9:45:11 AM														
2/15/2001 11:35:00 AM														
2/15/2001 11:43:00 AM														
2/16/2001 10:55:00 AM														
2/16/2001 11:33:00 AM														
2/21/2001 8:05:16 AM					<	0.5	<	0.5						
8/21/2002 5:19:06 AM					<	0.5	<	0.5						
9/18/2002 5:00:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.3	<	0.01		
12/18/2002 6:12:00 AM					<	0.5	<	0.5						
9/17/2003 7:40:00 AM	<	0.02	<	0.01	<	0.5	<	0.5	<	0.1		0.02		
9/17/2003 7:45:00 AM														
10/15/2003 7:50:00 AM					<	0.5	<	0.5						
11/19/2003 7:40:00 AM														
12/17/2003 7:20:00 AM														
12/17/2003 7:25:00 AM														
1/21/2004 8:20:00 AM					<	0.5	<	0.5						
count		10		10		50		50		10		10		5
# NDs		10		10		50		50		10		9		4
average		0.02		0.01		0.5		0.5		0.28		0.011		1.26
stand dev		0		0		0		0		0.06		0.003		0.58

Attachment 2. Banks Pum

Collection Date		Demeton (Demeton O + Demeton S)		Diazinon		Dibromoacetic Acid (DBAA)		Dibromoacetonitrile		Dibromomethane		Dicamba		Dichloran
6/22/1995 9:55:00 AM														
7/20/1995 10:38:00 AM														
8/17/1995 9:15:00 AM														
9/14/1995 9:43:00 AM														
10/19/1995 10:30:00 AM														
11/16/1995 11:00:00 AM														
12/7/1995 11:47:00 AM	<	0.5	<	0.25			<	0.5	<	0.5	<	0.08		
1/18/1996 11:42:00 AM														
2/15/1996 11:24:00 AM														
3/14/1996 12:35:00 PM	<	0.5	<	0.25			<	0.5			<	0.08		
4/11/1996 10:26:00 AM						8.1								
5/9/1996 10:40:00 AM						3.7								
6/13/1996 12:25:00 PM	<	0.5	<	0.25	<	1	<	0.5	<	0.5	<	0.08		
7/18/1996 12:20:00 PM					<	1								
8/15/1996 9:51:00 AM						1.4								
9/12/1996 12:30:00 PM	<	0.5	<	0.25	<	1	<	0.5	<	0.5	<	0.08		
10/10/1996 9:53:00 AM						5.8								
11/14/1996 12:35:00 PM						4.7								
12/12/1996 12:45:00 PM	<	0.5	<	0.25		14.5	<	0.5	<	0.5	<	0.08		
1/7/1997 2:08:00 PM					<	1								
2/13/1997 11:20:00 AM					<	1								
3/13/1997 12:30:00 PM						2								
4/9/1997 10:50:00 AM						4.8			<	0.5				
5/13/1997 11:15:00 AM						5			<	0.5				
6/4/1997 9:28:00 AM						3								
7/2/1997 12:30:00 PM						1			<	0.5				
12/17/1997 9:50:00 AM									<	0.5				
1/21/1998 9:00:00 AM														
2/18/1998 8:20:00 AM					<	1			<	0.5				
3/18/1998 8:50:00 AM	<	0.02	<	0.01	<	1			<	0.5	<	0.1	<	0.01
4/15/1998 6:30:00 AM					<	1			<	0.5				
5/20/1998 6:00:00 AM					<	1			<	0.5				
6/17/1998 7:05:00 AM	<	0.02	<	0.01	<	1			<	0.5	<	0.1	<	0.01
7/15/1998 7:45:00 AM						3			<	0.5				
8/19/1998 5:50:00 AM					<	1			<	0.5				
9/16/1998 8:00:00 AM	<	0.02	<	0.01	<	1			<	0.5	<	0.1	<	0.01
10/21/1998 6:25:00 AM						3			<	0.5				
11/18/1998 8:20:00 AM						2			<	0.5				
12/16/1998 8:55:00 AM						9			<	0.5				
1/20/1999 8:25:00 AM						4			<	0.5				
2/17/1999 7:30:00 AM						5.2			<	0.5				
3/17/1999 8:40:00 AM	<	0.02	<	0.01	<	1			<	0.5	<	0.1	<	0.01
4/21/1999 7:13:00 AM						5			<	0.5				
5/19/1999 7:20:00 AM						4			<	0.5				
6/16/1999 8:00:00 AM	<	0.02	<	0.01		4			<	0.5	<	0.1	<	0.01
7/21/1999 7:30:00 AM					<	1			<	0.5				
8/18/1999 6:35:00 AM									<	0.5				
9/15/1999 9:55:00 AM	<	0.02	<	0.01					<	0.5	<	0.1	<	0.01
10/20/1999 6:45:00 AM									<	0.5				
11/17/1999 7:25:00 AM									<	0.5				
12/15/1999 6:50:00 AM									<	0.5				
1/19/2000 8:20:00 AM									<	0.5				
2/16/2000 8:20:00 AM									<	0.5				
3/15/2000 8:25:00 AM	<	0.02	<	0.01					<	0.5	<	0.1	<	0.01
4/19/2000 6:30:00 AM									<	0.5				
5/17/2000 6:40:00 AM									<	0.5				
6/21/2000 6:50:00 AM	<	0.02	<	0.01					<	0.5	<	0.1	<	0.01
7/19/2000 8:40:00 AM									<	0.5				
8/16/2000 6:45:00 AM									<	0.5				
9/20/2000 7:30:00 AM									<	0.5				
10/18/2000 6:50:00 AM									<	0.5				
11/15/2000 8:05:00 AM									<	0.5				
12/20/2000 9:50:00 AM									<	0.5				
12/27/2000 9:00:00 AM														
1/10/2001 8:55:48 AM														
1/10/2001 9:00:00 AM														
1/10/2001 9:05:48 AM														
1/17/2001 9:45:11 AM														
2/15/2001 11:35:00 AM														
2/15/2001 11:43:00 AM														
2/16/2001 10:55:00 AM														
2/16/2001 11:33:00 AM														
2/21/2001 8:05:16 AM									<	0.5				
8/21/2002 5:19:06 AM									<	0.5				
9/18/2002 5:00:00 AM		0.02		0.01					<	0.5	<	0.1	<	0.01
12/18/2002 6:12:00 AM									<	0.5				
9/17/2003 7:40:00 AM		0.1		0.01					<	0.5	<	0.1		0
9/17/2003 7:45:00 AM														
10/15/2003 7:50:00 AM									<	0.5				
11/19/2003 7:40:00 AM														
12/17/2003 7:20:00 AM														
12/17/2003 7:25:00 AM														
1/21/2004 8:20:00 AM									<	0.5				
count		15		15		34		5		50		15		10
# NDs		13		13		14		5		50		15		9
average		0.19		0.09		3.15		0.5		0.5		0.09		0.009
stand dev		0.23		0.12		2.96		0		0		0.01		0.0032

Attachment 2. Banks Pump

Collection Date		Dichloroacetic Acid (DCAA)		Dichloroacetonitrile		Dichlorodifluoromethane		Dichlorprop		Dicofol		Dieldrin		Dimethoate		Dinoseb (DNPB)
6/22/1995 9:55:00 AM																
7/20/1995 10:38:00 AM																
8/17/1995 9:15:00 AM																
9/14/1995 9:43:00 AM																
10/19/1995 10:30:00 AM																
11/16/1995 11:00:00 AM																
12/7/1995 11:47:00 AM			<	1	<	0.5					<	0.02	<	10	<	0.2
1/18/1996 11:42:00 AM																
2/15/1996 11:24:00 AM																
3/14/1996 12:35:00 PM			<	1							<	0.02	<	10	<	0.2
4/11/1996 10:26:00 AM		37														
5/9/1996 10:40:00 AM		26														
6/13/1996 12:25:00 PM		31	<	1	<	0.5					<	0.02	<	10	<	0.2
7/18/1996 12:20:00 PM		33														
8/15/1996 9:51:00 AM		33														
9/12/1996 12:30:00 PM		26	<	1	<	0.5					<	0.07	<	10	<	0.2
10/10/1996 9:53:00 AM		61														
11/14/1996 12:35:00 PM		23														
12/12/1996 12:45:00 PM		59	<	1	<	0.5					<	0.07	<	10	<	0.2
1/7/1997 2:08:00 PM		53														
2/13/1997 11:20:00 AM		67														
3/13/1997 12:30:00 PM		49														
4/9/1997 10:50:00 AM		62			<	0.5										
5/13/1997 11:15:00 AM		29			<	0.5										
6/4/1997 9:28:00 AM		30														
7/2/1997 12:30:00 PM		27			<	0.5										
12/17/1997 9:50:00 AM					<	0.5										
1/21/1998 9:00:00 AM																
2/18/1998 8:20:00 AM		65			<	0.5										
3/18/1998 8:50:00 AM		60			<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
4/15/1998 6:30:00 AM		54			<	0.5										
5/20/1998 6:00:00 AM		58			<	0.5										
6/17/1998 7:05:00 AM		50			<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
7/15/1998 7:45:00 AM		48			<	0.5										
8/19/1998 5:50:00 AM		49			<	0.5										
9/16/1998 8:00:00 AM		47			<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
10/21/1998 6:25:00 AM		40			<	0.5										
11/18/1998 8:20:00 AM		68			<	0.5										
12/16/1998 8:55:00 AM		46			<	0.5										
1/20/1999 8:25:00 AM		62			<	0.5										
2/17/1999 7:30:00 AM		103			<	0.5										
3/17/1999 8:40:00 AM		34			<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
4/21/1999 7:13:00 AM		58			<	0.5										
5/19/1999 7:20:00 AM		45			<	0.5										
6/16/1999 8:00:00 AM		58			<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
7/21/1999 7:30:00 AM		49			<	0.5										
8/18/1999 6:35:00 AM					<	0.5										
9/15/1999 9:55:00 AM					<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
10/20/1999 6:45:00 AM					<	0.5										
11/17/1999 7:25:00 AM					<	0.5										
12/15/1999 6:50:00 AM					<	0.5										
1/19/2000 8:20:00 AM					<	0.5										
2/16/2000 8:20:00 AM					<	0.5										
3/15/2000 8:25:00 AM					<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
4/19/2000 6:30:00 AM					<	0.5										
5/17/2000 6:40:00 AM					<	0.5										
6/21/2000 6:50:00 AM					<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
7/19/2000 8:40:00 AM					<	0.5										
8/16/2000 6:45:00 AM					<	0.5										
9/20/2000 7:30:00 AM					<	0.5										
10/18/2000 6:50:00 AM					<	0.5										
11/15/2000 8:05:00 AM					<	0.5										
12/20/2000 9:50:00 AM					<	0.5										
12/27/2000 9:00:00 AM																
1/10/2001 8:55:48 AM																
1/10/2001 9:00:00 AM																
1/10/2001 9:05:48 AM																
1/17/2001 9:45:11 AM																
2/15/2001 11:35:00 AM																
2/15/2001 11:43:00 AM																
2/16/2001 10:55:00 AM																
2/16/2001 11:33:00 AM																
2/21/2001 8:05:16 AM					<	0.5										
8/21/2002 5:19:06 AM					<	0.5										
9/18/2002 5:00:00 AM					<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
12/18/2002 6:12:00 AM					<	0.5										
9/17/2003 7:40:00 AM					<	0.5	<	0.1	<	0.05	<	0.01	<	0.01	<	0.1
9/17/2003 7:45:00 AM																
10/15/2003 7:50:00 AM					<	0.5										
11/19/2003 7:40:00 AM																
12/17/2003 7:20:00 AM																
12/17/2003 7:25:00 AM																
1/21/2004 8:20:00 AM					<	0.5										
count		34		5		50		10		10		15		15		15
# NDs		0		5		50		10		10		15		15		15
average		48.2		1		0.5		0.1		0.05		0.02		3.34		0.13
stand dev		16.6		0		0		0		0		0.02		4.87		0.05

Attachment 2. Banks Pum

Collection Date		Diquat		Disulfoton		Diuron		Endosulfan sulfate		Endosulfan-I		Endosulfan-II		Endothal		Endrin		Endrin aldehyde
6/22/1995 9:55:00 AM																		
7/20/1995 10:38:00 AM																		
8/17/1995 9:15:00 AM																		
9/14/1995 9:43:00 AM																		
10/19/1995 10:30:00 AM																		
11/16/1995 11:00:00 AM																		
12/7/1995 11:47:00 AM	<	4	<	0.5									<	45	<	0.01		
1/18/1996 11:42:00 AM																		
2/15/1996 11:24:00 AM																		
3/14/1996 12:35:00 PM	<	4	<	0.5									<	45	<	0.01		
4/11/1996 10:26:00 AM																		
5/9/1996 10:40:00 AM																		
6/13/1996 12:25:00 PM	<	4	<	0.5									<	45	<	0.01		
7/18/1996 12:20:00 PM																		
8/15/1996 9:51:00 AM																		
9/12/1996 12:30:00 PM	<	4	<	0.5									<	45	<	0.1		
10/10/1996 9:53:00 AM																		
11/14/1996 12:35:00 PM																		
12/12/1996 12:45:00 PM	<	4	<	0.5									<	45	<	0.1		
1/7/1997 2:08:00 PM																		
2/13/1997 11:20:00 AM																		
3/13/1997 12:30:00 PM																		
4/9/1997 10:50:00 AM																		
5/13/1997 11:15:00 AM																		
6/4/1997 9:28:00 AM																		
7/2/1997 12:30:00 PM																		
12/17/1997 9:50:00 AM																		
1/21/1998 9:00:00 AM																		
2/18/1998 8:20:00 AM																		
3/18/1998 8:50:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
4/15/1998 6:30:00 AM																		
5/20/1998 6:00:00 AM																		
6/17/1998 7:05:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
7/15/1998 7:45:00 AM																		
8/19/1998 5:50:00 AM																		
9/16/1998 8:00:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
10/21/1998 6:25:00 AM																		
11/18/1998 8:20:00 AM																		
12/16/1998 8:55:00 AM																		
1/20/1999 8:25:00 AM																		
2/17/1999 7:30:00 AM																		
3/17/1999 8:40:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
4/21/1999 7:13:00 AM																		
5/19/1999 7:20:00 AM																		
6/16/1999 8:00:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
7/21/1999 7:30:00 AM																		
8/18/1999 6:35:00 AM																		
9/15/1999 9:55:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
10/20/1999 6:45:00 AM																		
11/17/1999 7:25:00 AM																		
12/15/1999 6:50:00 AM																		
1/19/2000 8:20:00 AM																		
2/16/2000 8:20:00 AM																		
3/15/2000 8:25:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
4/19/2000 6:30:00 AM																		
5/17/2000 6:40:00 AM																		
6/21/2000 6:50:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
7/19/2000 8:40:00 AM																		
8/16/2000 6:45:00 AM																		
9/20/2000 7:30:00 AM																		
10/18/2000 6:50:00 AM																		
11/15/2000 8:05:00 AM																		
12/20/2000 9:50:00 AM																		
12/27/2000 9:00:00 AM																		
1/10/2001 8:55:48 AM																		
1/10/2001 9:00:00 AM																		
1/10/2001 9:05:48 AM																		
1/17/2001 9:45:11 AM																		
2/15/2001 11:35:00 AM																		
2/15/2001 11:43:00 AM																		
2/16/2001 10:55:00 AM																		
2/16/2001 11:33:00 AM																		
2/21/2001 8:05:16 AM																		
8/21/2002 5:19:06 AM																		
9/18/2002 5:00:00 AM			<	0.01	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
12/18/2002 6:12:00 AM																		
9/17/2003 7:40:00 AM			<	0.1	<	0.25	<	0.02	<	0.01	<	0.01			<	0.01	<	0.01
9/17/2003 7:45:00 AM																		
10/15/2003 7:50:00 AM																		
11/19/2003 7:40:00 AM																		
12/17/2003 7:20:00 AM																		
12/17/2003 7:25:00 AM																		
1/21/2004 8:20:00 AM																		
count		5		15		10		10		10		10		5		15		10
# NDs		5		15		10		10		10		10		5		15		10
average		4		0.18		0.25		0.02		0.01		0.01		45		0.022		0.01
stand dev		0		0.24		0		0		0		0		0		0.03		0

Attachment 2. Banks Pumping Plant at California Aquaduct (all results in ug/L)

Collection Date	Escherichia coli	Esfenvalerate	Ethion	Ethyl benzene	Ethylene Dibromide	Ethylenethiourea	Formetanate hydrochloride	Glyphosate
6/22/1995 9:55:00 AM								
7/20/1995 10:38:00 AM								
8/17/1995 9:15:00 AM								
9/14/1995 9:43:00 AM								
10/19/1995 10:30:00 AM								
11/16/1995 11:00:00 AM								
12/7/1995 11:47:00 AM				< 0.5	< 0.02	< 25	< 100	< 100
1/18/1996 11:42:00 AM								
2/15/1996 11:24:00 AM								
3/14/1996 12:35:00 PM						< 5	< 100	< 100
4/11/1996 10:26:00 AM								
5/9/1996 10:40:00 AM								
6/13/1996 12:25:00 PM				< 0.5	< 0.02	< 5	< 100	< 100
7/18/1996 12:20:00 PM								
8/15/1996 9:51:00 AM								
9/12/1996 12:30:00 PM				< 0.5	< 0.02		< 100	< 100
10/10/1996 9:53:00 AM								
11/14/1996 12:35:00 PM	101							
12/12/1996 12:45:00 PM	476			< 0.5	< 0.02	< 5	< 100	< 100
1/7/1997 2:08:00 PM	32.4							
2/13/1997 11:20:00 AM	73.8							
3/13/1997 12:30:00 PM	40.6							
4/9/1997 10:50:00 AM	27.1			< 0.5				
5/13/1997 11:15:00 AM	3.1			< 0.5				
6/4/1997 9:28:00 AM	4.2							
7/2/1997 12:30:00 PM	3.1			< 0.5				
12/17/1997 9:50:00 AM				< 0.5				
1/21/1998 9:00:00 AM								
2/18/1998 8:20:00 AM				< 0.5				
3/18/1998 8:50:00 AM			< 0.01	< 0.5			< 100	< 100
4/15/1998 6:30:00 AM				< 0.5				
5/20/1998 6:00:00 AM				< 0.5				
6/17/1998 7:05:00 AM			< 0.01	< 0.5			< 100	< 100
7/15/1998 7:45:00 AM				< 0.5				
8/19/1998 5:50:00 AM				< 0.5				
9/16/1998 8:00:00 AM			< 0.01	< 0.5			< 100	< 100
10/21/1998 6:25:00 AM				< 0.5				
11/18/1998 8:20:00 AM				< 0.5				
12/16/1998 8:55:00 AM				< 0.5				
1/20/1999 8:25:00 AM				< 0.5				
2/17/1999 7:30:00 AM				< 0.5				
3/17/1999 8:40:00 AM			< 0.01	< 0.5			< 100	< 100
4/21/1999 7:13:00 AM				< 0.5				
5/19/1999 7:20:00 AM				< 0.5				
6/16/1999 8:00:00 AM			< 0.01	< 0.5			< 100	< 100
7/21/1999 7:30:00 AM				< 0.5				
8/18/1999 6:35:00 AM				< 0.5				
9/15/1999 9:55:00 AM			< 0.01	< 0.5			< 100	< 100
10/20/1999 6:45:00 AM				< 0.5				
11/17/1999 7:25:00 AM				< 0.5				
12/15/1999 6:50:00 AM				< 0.5				
1/19/2000 8:20:00 AM				< 0.5				
2/16/2000 8:20:00 AM				< 0.5				
3/15/2000 8:25:00 AM			< 0.01	< 0.5			< 100	< 100
4/19/2000 6:30:00 AM				< 0.5				
5/17/2000 6:40:00 AM				< 0.5				
6/21/2000 6:50:00 AM			< 0.01	< 0.5			< 100	< 100
7/19/2000 8:40:00 AM				< 0.5				
8/16/2000 6:45:00 AM				< 0.5				
9/20/2000 7:30:00 AM				< 0.5				
10/18/2000 6:50:00 AM				< 0.5				
11/15/2000 8:05:00 AM				< 0.5				
12/20/2000 9:50:00 AM				< 0.5				
12/27/2000 9:00:00 AM								
1/10/2001 8:55:48 AM								
1/10/2001 9:00:00 AM								
1/10/2001 9:05:48 AM								
1/17/2001 9:45:11 AM								
2/15/2001 11:35:00 AM								
2/15/2001 11:43:00 AM								
2/16/2001 10:55:00 AM								
2/16/2001 11:33:00 AM								
2/21/2001 8:05:16 AM				< 0.5				
8/21/2002 5:19:06 AM				< 0.5				
9/18/2002 5:00:00 AM			< 0.01	< 0.5				
12/18/2002 6:12:00 AM				< 0.5				
9/17/2003 7:40:00 AM		< 0.02	< 0.01	< 0.5			< 100	< 25
9/17/2003 7:45:00 AM								
10/15/2003 7:50:00 AM				< 0.5				
11/19/2003 7:40:00 AM								
12/17/2003 7:20:00 AM								
12/17/2003 7:25:00 AM								
1/21/2004 8:20:00 AM				< 0.5				
count	9	1	10	50	4	4	14	14
# NDs	0	1	10	50	4	4	14	14
average	84.6	0.02	0.01	0.50	0.02	10	100	94.64
stand dev	151		0	0	0	10.0	0	20.0

Attachment 2. Banks Pump

Collection Date		Heptachlor		Heptachlor epoxide		Hexachlorobenzene		Hexachlorobutadiene		Hexachlorocyclopentadiene		Isopropylbenzene		m + p Xylene
6/22/1995 9:55:00 AM														
7/20/1995 10:38:00 AM														
8/17/1995 9:15:00 AM														
9/14/1995 9:43:00 AM														
10/19/1995 10:30:00 AM														
11/16/1995 11:00:00 AM														
12/7/1995 11:47:00 AM	<	0.01	<	0.01	<	0.1	<	0.5	<	0.1	<	0.5		
1/18/1996 11:42:00 AM														
2/15/1996 11:24:00 AM														
3/14/1996 12:35:00 PM	<	0.01	<	0.01	<	0.1			<	0.1				
4/11/1996 10:26:00 AM														
5/9/1996 10:40:00 AM														
6/13/1996 12:25:00 PM	<	0.01	<	0.01	<	0.1	<	0.5	<	0.1	<	0.5		
7/18/1996 12:20:00 PM														
8/15/1996 9:51:00 AM														
9/12/1996 12:30:00 PM	<	0.01	<	0.01	<	0.5	<	0.5	<	1	<	0.5		
10/10/1996 9:53:00 AM														
11/14/1996 12:35:00 PM														
12/12/1996 12:45:00 PM	<	0.01	<	0.01	<	0.5	<	0.5	<	1	<	0.5		
1/7/1997 2:08:00 PM														
2/13/1997 11:20:00 AM														
3/13/1997 12:30:00 PM														
4/9/1997 10:50:00 AM							<	0.5			<	0.5		
5/13/1997 11:15:00 AM							<	0.5			<	0.5		
6/4/1997 9:28:00 AM														
7/2/1997 12:30:00 PM							<	0.5			<	0.5		
12/17/1997 9:50:00 AM							<	0.5			<	0.5		
1/21/1998 9:00:00 AM														
2/18/1998 8:20:00 AM							<	0.5			<	0.5		
3/18/1998 8:50:00 AM	<	0.01	<	0.01			<	0.5			<	0.5		
4/15/1998 6:30:00 AM							<	0.5			<	0.5		
5/20/1998 6:00:00 AM							<	0.5			<	0.5		
6/17/1998 7:05:00 AM	<	0.01	<	0.01			<	0.5			<	0.5		
7/15/1998 7:45:00 AM							<	0.5			<	0.5	<	0.5
8/19/1998 5:50:00 AM							<	0.5			<	0.5	<	0.5
9/16/1998 8:00:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
10/21/1998 6:25:00 AM							<	0.5			<	0.5	<	0.5
11/18/1998 8:20:00 AM							<	0.5			<	0.5	<	0.5
12/16/1998 8:55:00 AM							<	0.5			<	0.5	<	0.5
1/20/1999 8:25:00 AM							<	0.5			<	0.5	<	0.5
2/17/1999 7:30:00 AM							<	0.5			<	0.5	<	0.5
3/17/1999 8:40:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
4/21/1999 7:13:00 AM							<	0.5			<	0.5	<	0.5
5/19/1999 7:20:00 AM							<	0.5			<	0.5	<	0.5
6/16/1999 8:00:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
7/21/1999 7:30:00 AM							<	0.5			<	0.5	<	0.5
8/18/1999 6:35:00 AM							<	0.5			<	0.5	<	0.5
9/15/1999 9:55:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
10/20/1999 6:45:00 AM							<	0.5			<	0.5	<	0.5
11/17/1999 7:25:00 AM							<	0.5			<	0.5	<	0.5
12/15/1999 6:50:00 AM							<	0.5			<	0.5	<	0.5
1/19/2000 8:20:00 AM							<	0.5			<	0.5	<	0.5
2/16/2000 8:20:00 AM							<	0.5			<	0.5	<	0.5
3/15/2000 8:25:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
4/19/2000 6:30:00 AM							<	0.5			<	0.5	<	0.5
5/17/2000 6:40:00 AM							<	0.5			<	0.5	<	0.5
6/21/2000 6:50:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
7/19/2000 8:40:00 AM							<	0.5			<	0.5	<	0.5
8/16/2000 6:45:00 AM							<	0.5			<	0.5	<	0.5
9/20/2000 7:30:00 AM							<	0.5			<	0.5	<	0.5
10/18/2000 6:50:00 AM							<	0.5			<	0.5	<	0.5
11/15/2000 8:05:00 AM							<	0.5			<	0.5	<	0.5
12/20/2000 9:50:00 AM							<	0.5			<	0.5	<	0.5
12/27/2000 9:00:00 AM														
1/10/2001 8:55:48 AM														
1/10/2001 9:00:00 AM														
1/10/2001 9:05:48 AM														
1/17/2001 9:45:11 AM														
2/15/2001 11:35:00 AM														
2/15/2001 11:43:00 AM														
2/16/2001 10:55:00 AM														
2/16/2001 11:33:00 AM														
2/21/2001 8:05:16 AM							<	0.5			<	0.5	<	0.5
8/21/2002 5:19:06 AM							<	0.5			<	0.5	<	0.5
9/18/2002 5:00:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
12/18/2002 6:12:00 AM							<	0.5			<	0.5	<	0.5
9/17/2003 7:40:00 AM	<	0.01	<	0.01			<	0.5			<	0.5	<	0.5
9/17/2003 7:45:00 AM														
10/15/2003 7:50:00 AM							<	0.5			<	0.5	<	0.5
11/19/2003 7:40:00 AM														
12/17/2003 7:20:00 AM														
12/17/2003 7:25:00 AM														
1/21/2004 8:20:00 AM							<	0.5			<	0.5	<	0.5
count		15		15		5		50		5		50		37
# NDs		15		15		5		50		5		50		37
average		0.01		0.01		0.26		0.50		0.46		0.50		0.50
stand dev		0		0		0.22		0		0		0		0

Attachment 2. Banks Pump

Collection Date	Malathion	MCPA	MCPP	Methamidophos	Methidathion	Methiocarb	Methomyl	Methoxychlor	Methyl tert-butyl ether (MTBE)
6/22/1995 9:55:00 AM									
7/20/1995 10:38:00 AM									
8/17/1995 9:15:00 AM									
9/14/1995 9:43:00 AM									
10/19/1995 10:30:00 AM									
11/16/1995 11:00:00 AM									
12/7/1995 11:47:00 AM						< 4	< 2	< 0.1	
1/18/1996 11:42:00 AM									
2/15/1996 11:24:00 AM									
3/14/1996 12:35:00 PM						< 4	< 2		
4/11/1996 10:26:00 AM									
5/9/1996 10:40:00 AM									
6/13/1996 12:25:00 PM						< 4	< 2	< 0.1	
7/18/1996 12:20:00 PM									
8/15/1996 9:51:00 AM									
9/12/1996 12:30:00 PM						< 4	< 2	< 10	
10/10/1996 9:53:00 AM									
11/14/1996 12:35:00 PM									
12/12/1996 12:45:00 PM						< 4	< 2	< 10	
1/7/1997 2:08:00 PM									
2/13/1997 11:20:00 AM									
3/13/1997 12:30:00 PM									
4/9/1997 10:50:00 AM									0.5
5/13/1997 11:15:00 AM									< 1.00
6/4/1997 9:28:00 AM									< 1.00
7/2/1997 12:30:00 PM									< 1.00
12/17/1997 9:50:00 AM									< 1.00
1/21/1998 9:00:00 AM									
2/18/1998 8:20:00 AM									< 1.00
3/18/1998 8:50:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
4/15/1998 6:30:00 AM									< 1.00
5/20/1998 6:00:00 AM									< 1.00
6/17/1998 7:05:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
7/15/1998 7:45:00 AM									< 1.00
8/19/1998 5:50:00 AM									< 1.00
9/16/1998 8:00:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	1.6
10/21/1998 6:25:00 AM									1.4
11/18/1998 8:20:00 AM									< 1.00
12/16/1998 8:55:00 AM									< 1.00
1/20/1999 8:25:00 AM									< 1.00
2/17/1999 7:30:00 AM									< 1.00
3/17/1999 8:40:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
4/21/1999 7:13:00 AM									< 1.00
5/19/1999 7:20:00 AM									< 1.00
6/16/1999 8:00:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
7/21/1999 7:30:00 AM									< 1.00
8/18/1999 6:35:00 AM									< 1.00
9/15/1999 9:55:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	1
10/20/1999 6:45:00 AM									1.9
11/17/1999 7:25:00 AM									1.8
12/15/1999 6:50:00 AM									< 1.00
1/19/2000 8:20:00 AM									1
2/16/2000 8:20:00 AM									< 1.00
3/15/2000 8:25:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
4/19/2000 6:30:00 AM									< 1.00
5/17/2000 6:40:00 AM									< 1.00
6/21/2000 6:50:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
7/19/2000 8:40:00 AM									< 1.00
8/16/2000 6:45:00 AM									1.1
9/20/2000 7:30:00 AM									1.6
10/18/2000 6:50:00 AM									1.7
11/15/2000 8:05:00 AM									< 1.00
12/20/2000 9:50:00 AM									1
12/27/2000 9:00:00 AM									
1/10/2001 8:55:48 AM									
1/10/2001 9:00:00 AM									
1/10/2001 9:05:48 AM									
1/17/2001 9:45:11 AM									< 1.00
2/15/2001 11:35:00 AM									
2/15/2001 11:43:00 AM									
2/16/2001 10:55:00 AM									
2/16/2001 11:33:00 AM									
2/21/2001 8:05:16 AM									< 1.00
8/21/2002 5:19:06 AM									< 1.00
9/18/2002 5:00:00 AM	< 0.01	< 0.1	< 0.1		< 0.02			< 0.05	< 1.00
12/18/2002 6:12:00 AM									< 1.00
9/17/2003 7:40:00 AM	< 0.01	< 0.1	< 0.1		< 0.02	< 4	< 2	< 0.05	< 1.00
9/17/2003 7:45:00 AM									
10/15/2003 7:50:00 AM									< 1.00
11/19/2003 7:40:00 AM									
12/17/2003 7:20:00 AM									
12/17/2003 7:25:00 AM									
1/21/2004 8:20:00 AM									< 1.00
count	10	10	10		10	14	14	14	48
# NDs	10	10	10		10	14	14	14	37
average	0.01	0.10	0.10		0.02	4.00	2.00	1.48	1.08
stand dev	0	0	0		0	0	0	3.6	0.24

Attachment 2. Banks Pump

Collection Date		Methylene chloride		Metolachlor		Metribuzin		Mevinphos		Molinate		Monobromoacetic Acid (MBAA)		Monochloroacetic Acid (MCAA)
6/22/1995 9:55:00 AM														
7/20/1995 10:38:00 AM														
8/17/1995 9:15:00 AM														
9/14/1995 9:43:00 AM														
10/19/1995 10:30:00 AM														
11/16/1995 11:00:00 AM														
12/7/1995 11:47:00 AM	<	0.5	<	0.5	<	0.5			<	2				
1/18/1996 11:42:00 AM														
2/15/1996 11:24:00 AM														
3/14/1996 12:35:00 PM			<	0.5	<	0.5			<	2				
4/11/1996 10:26:00 AM												1	<	1.00
5/9/1996 10:40:00 AM												2.5	<	1.00
6/13/1996 12:25:00 PM	<	0.5	<	0.5	<	0.5			<	2	<	1.00	<	1.00
7/18/1996 12:20:00 PM												1.7	<	1.00
8/15/1996 9:51:00 AM												1	<	1.00
9/12/1996 12:30:00 PM	<	0.5	<	0.5	<	0.5			<	2	<	1.00	<	1.00
10/10/1996 9:53:00 AM											<	1.00	<	1.00
11/14/1996 12:35:00 PM											<	1.00	<	1.00
12/12/1996 12:45:00 PM	<	0.5	<	0.5	<	0.5			<	2		2.1	<	1.00
1/7/1997 2:08:00 PM											<	1.00	<	1.00
2/13/1997 11:20:00 AM											<	1.00	<	1.00
3/13/1997 12:30:00 PM											<	1.00	<	1.00
4/9/1997 10:50:00 AM	<	0.5									<	1.00	<	1.00
5/13/1997 11:15:00 AM	<	0.5									<	1.00	<	1.00
6/4/1997 9:28:00 AM											<	1.00	<	1.00
7/2/1997 12:30:00 PM	<	0.5									<	1.00	<	1.00
12/17/1997 9:50:00 AM	<	0.5												
1/21/1998 9:00:00 AM														
2/18/1998 8:20:00 AM	<	0.5									<	1.00	<	1.00
3/18/1998 8:50:00 AM	<	0.5	<	0.2			<	0.01			<	1.00	<	1.00
4/15/1998 6:30:00 AM	<	0.5									<	1.00	<	1.00
5/20/1998 6:00:00 AM	<	0.5									<	1.00	<	1.00
6/17/1998 7:05:00 AM	<	0.5	<	0.2			<	0.01			<	1.00	<	1.00
7/15/1998 7:45:00 AM	<	0.5									<	1.00	<	1.00
8/19/1998 5:50:00 AM	<	0.5									<	1.00	<	1.00
9/16/1998 8:00:00 AM	<	0.5	<	0.2			<	0.01			<	1.00	<	1.00
10/21/1998 6:25:00 AM	<	0.5									<	1.00	<	1.00
11/18/1998 8:20:00 AM	<	0.5									<	1.00	<	1.00
12/16/1998 8:55:00 AM	<	0.5									<	1.00	<	1.00
1/20/1999 8:25:00 AM	<	0.5									<	1.00	<	1.00
2/17/1999 7:30:00 AM	<	0.5									<	1.00	<	1.00
3/17/1999 8:40:00 AM	<	0.5	<	0.2			<	0.01			<	1.00	<	1.00
4/21/1999 7:13:00 AM	<	0.5									<	1.00	<	1.00
5/19/1999 7:20:00 AM	<	0.5									<	1.00	<	1.00
6/16/1999 8:00:00 AM	<	0.5	<	0.2			<	0.01			<	1.00	<	1.00
7/21/1999 7:30:00 AM	<	0.5									<	1.00	<	1.00
8/18/1999 6:35:00 AM	<	0.5												
9/15/1999 9:55:00 AM	<	0.5	<	0.2			<	0.01						
10/20/1999 6:45:00 AM	<	0.5												
11/17/1999 7:25:00 AM	<	0.5												
12/15/1999 6:50:00 AM	<	0.5												
1/19/2000 8:20:00 AM	<	0.5												
2/16/2000 8:20:00 AM	<	0.5												
3/15/2000 8:25:00 AM	<	0.5	<	0.2			<	0.01						
4/19/2000 6:30:00 AM	<	0.5												
5/17/2000 6:40:00 AM	<	0.5												
6/21/2000 6:50:00 AM	<	0.5	<	0.2			<	0.01						
7/19/2000 8:40:00 AM	<	0.5												
8/16/2000 6:45:00 AM	<	0.5												
9/20/2000 7:30:00 AM	<	0.5												
10/18/2000 6:50:00 AM	<	0.5												
11/15/2000 8:05:00 AM	<	0.5												
12/20/2000 9:50:00 AM	<	0.5												
12/27/2000 9:00:00 AM														
1/10/2001 8:55:48 AM														
1/10/2001 9:00:00 AM														
1/10/2001 9:05:48 AM														
1/17/2001 9:45:11 AM														
2/15/2001 11:35:00 AM														
2/15/2001 11:43:00 AM														
2/16/2001 10:55:00 AM														
2/16/2001 11:33:00 AM														
2/21/2001 8:05:16 AM	<	0.5												
8/21/2002 5:19:06 AM	<	0.5												
9/18/2002 5:00:00 AM	<	0.5	<	0.2			<	0.01						
12/18/2002 6:12:00 AM	<	0.5												
9/17/2003 7:40:00 AM	<	0.5	<	0.05			<	0.01	<	0.02				
9/17/2003 7:45:00 AM														
10/15/2003 7:50:00 AM	<	0.5												
11/19/2003 7:40:00 AM														
12/17/2003 7:20:00 AM														
12/17/2003 7:25:00 AM														
1/21/2004 8:20:00 AM	<	0.5												

	Methylene chloride	Metolachlor	Metribuzin	Mevinphos	Molinate	Monobromoacetic Acid (MBAA)	Monochloroacetic Acid (MCAA)
count	50	15	5	10	6	34	34
# NDs	50	15	5	10	6	29	34
average	0.50	0.29	0.50	0.01	1.67	1.10	1.00
stand dev	0	0	0	0	0.8	0	0

Attachment 2. Banks Pump

Collection Date	m-Xylene	Naled	Naphthalene	Napropamide	n-Butylbenzene	Norflurazon	n-Propylbenzene	o,p'-DDE	Ortho-phosphate	Oxamyl
6/22/1995 9:55:00 AM										
7/20/1995 10:38:00 AM										
8/17/1995 9:15:00 AM										
9/14/1995 9:43:00 AM										
10/19/1995 10:30:00 AM										
11/16/1995 11:00:00 AM										
12/7/1995 11:47:00 AM	< 0.5		< 0.5		< 0.5		< 0.5			< 2
1/18/1996 11:42:00 AM										
2/15/1996 11:24:00 AM										
3/14/1996 12:35:00 PM										< 2
4/11/1996 10:26:00 AM										
5/9/1996 10:40:00 AM										
6/13/1996 12:25:00 PM	< 0.5		< 0.5		< 0.5		< 0.5			< 2
7/18/1996 12:20:00 PM										
8/15/1996 9:51:00 AM										
9/12/1996 12:30:00 PM	< 0.5		< 0.5		< 0.5		< 0.5			< 2
10/10/1996 9:53:00 AM										
11/14/1996 12:35:00 PM										
12/12/1996 12:45:00 PM	< 0.5		< 0.5		< 0.5		< 0.5			< 2
1/7/1997 2:08:00 PM										
2/13/1997 11:20:00 AM										
3/13/1997 12:30:00 PM										
4/9/1997 10:50:00 AM	< 0.5		< 0.5		< 0.5		< 0.5			
5/13/1997 11:15:00 AM	< 0.5		< 0.5		< 0.5		< 0.5			
6/4/1997 9:28:00 AM										
7/2/1997 12:30:00 PM	< 0.5		< 0.5		< 0.5		< 0.5			
12/17/1997 9:50:00 AM	< 0.5		< 0.5		< 0.5		< 0.5		0.06	
1/21/1998 9:00:00 AM									0.11	
2/18/1998 8:20:00 AM	< 0.5		< 0.5		< 0.5		< 0.5		0.13	
3/18/1998 8:50:00 AM	< 0.5	< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.13	< 2
4/15/1998 6:30:00 AM	< 0.5		< 0.5		< 0.5		< 0.5		0.13	
5/20/1998 6:00:00 AM	< 0.5		< 0.5		< 0.5		< 0.5		0.11	
6/17/1998 7:05:00 AM	< 0.5	< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.08	< 2
7/15/1998 7:45:00 AM	< 0.5		< 0.5		< 0.5		< 0.5		0.07	
8/19/1998 5:50:00 AM			< 0.5		< 0.5		< 0.5		0.07	
9/16/1998 8:00:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.07	< 2
10/21/1998 6:25:00 AM			< 0.5		< 0.5		< 0.5		0.06	
11/18/1998 8:20:00 AM			< 0.5		< 0.5		< 0.5		0.05	
12/16/1998 8:55:00 AM			< 0.5		< 0.5		< 0.5		0.13	
1/20/1999 8:25:00 AM			< 0.5		< 0.5		< 0.5		0.06	
2/17/1999 7:30:00 AM			< 0.5		< 0.5		< 0.5		0.08	
3/17/1999 8:40:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.06	< 2
4/21/1999 7:13:00 AM			< 0.5		< 0.5		< 0.5		0.06	
5/19/1999 7:20:00 AM			< 0.5		< 0.5		< 0.5		0.08	
6/16/1999 8:00:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.09	< 2
7/21/1999 7:30:00 AM			< 0.5		< 0.5		< 0.5		0.06	
8/18/1999 6:35:00 AM			< 0.5		< 0.5		< 0.5		0.05	
9/15/1999 9:55:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.06	< 2
10/20/1999 6:45:00 AM			< 0.5		< 0.5		< 0.5		0.06	
11/17/1999 7:25:00 AM			< 0.5		< 0.5		< 0.5		0.04	
12/15/1999 6:50:00 AM			< 0.5		< 0.5		< 0.5		0.06	
1/19/2000 8:20:00 AM			< 0.5		< 0.5		< 0.5		0.05	
2/16/2000 8:20:00 AM			< 0.5		< 0.5		< 0.5		0.09	
3/15/2000 8:25:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.08	< 2
4/19/2000 6:30:00 AM			< 0.5		< 0.5		< 0.5		0.05	
5/17/2000 6:40:00 AM			< 0.5		< 0.5		< 0.5		0.07	
6/21/2000 6:50:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5		0.15	< 2
7/19/2000 8:40:00 AM			< 0.5		< 0.5		< 0.5		0.07	
8/16/2000 6:45:00 AM			< 0.5		< 0.5		< 0.5		0.06	
9/20/2000 7:30:00 AM			< 0.5		< 0.5		< 0.5		0.05	
10/18/2000 6:50:00 AM			< 0.5		< 0.5		< 0.5		0.06	
11/15/2000 8:05:00 AM			< 0.5		< 0.5		< 0.5		0.06	
12/20/2000 9:50:00 AM			< 0.5		< 0.5		< 0.5		0.06	
12/27/2000 9:00:00 AM										
1/10/2001 8:55:48 AM										
1/10/2001 9:00:00 AM										
1/10/2001 9:05:48 AM										
1/17/2001 9:45:11 AM									0.06	
2/15/2001 11:35:00 AM										
2/15/2001 11:43:00 AM										
2/16/2001 10:55:00 AM										
2/16/2001 11:33:00 AM										
2/21/2001 8:05:16 AM			< 0.5		< 0.5		< 0.5		0.08	
8/21/2002 5:19:06 AM			< 0.5		< 0.5		< 0.5			
9/18/2002 5:00:00 AM		< 0.02	< 0.5	< 5	< 0.5	< 5	< 0.5			
12/18/2002 6:12:00 AM			< 0.5		< 0.5		< 0.5		0.07	
9/17/2003 7:40:00 AM		< 0.02	< 0.5	< 0.05	< 0.5	< 0.05	< 0.5	< 0.01	0.06	< 2
9/17/2003 7:45:00 AM										
10/15/2003 7:50:00 AM			< 0.5		< 0.5		< 0.5		0.05	
11/19/2003 7:40:00 AM									0.08	
12/17/2003 7:20:00 AM									0.06	
12/17/2003 7:25:00 AM										
1/21/2004 8:20:00 AM			< 0.5		< 0.5		< 0.5			
count	14	10	50	10	50	10	50	1	44	14
# NDs	14	10	50	10	50	10	50	1	83	14
average	0.50	0.02	0.50	4.51	0.50	4.51	0.50	0.01	0.07	2.00
stand dev	0	0	0	1.6	0	1.6	0		0.026	0

Attachment 2. Banks Pump

Collection Date		Oxyfluorfen		o-Xylene		p,p'-DDD		p,p'-DDE		p,p'-DDT		Parathion (Ethyl)		Parathion, Methyl		PCB-1016		PCB-1221		PCB-1232
6/22/1995 9:55:00 AM																				
7/20/1995 10:38:00 AM																				
8/17/1995 9:15:00 AM																				
9/14/1995 9:43:00 AM																				
10/19/1995 10:30:00 AM																				
11/16/1995 11:00:00 AM																				
12/7/1995 11:47:00 AM			<	0.5																
1/18/1996 11:42:00 AM																				
2/15/1996 11:24:00 AM																				
3/14/1996 12:35:00 PM																				
4/11/1996 10:26:00 AM																				
5/9/1996 10:40:00 AM																				
6/13/1996 12:25:00 PM			<	0.5																
7/18/1996 12:20:00 PM																				
8/15/1996 9:51:00 AM																				
9/12/1996 12:30:00 PM			<	0.5																
10/10/1996 9:53:00 AM																				
11/14/1996 12:35:00 PM																				
12/12/1996 12:45:00 PM			<	0.5																
1/7/1997 2:08:00 PM																				
2/13/1997 11:20:00 AM																				
3/13/1997 12:30:00 PM																				
4/9/1997 10:50:00 AM			<	0.5																
5/13/1997 11:15:00 AM			<	0.5																
6/4/1997 9:28:00 AM																				
7/2/1997 12:30:00 PM			<	0.5																
12/17/1997 9:50:00 AM			<	0.5																
1/21/1998 9:00:00 AM																				
2/18/1998 8:20:00 AM			<	0.5																
3/18/1998 8:50:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.01	<	0.01	<	0.01
4/15/1998 6:30:00 AM			<	0.5																
5/20/1998 6:00:00 AM			<	0.5																
6/17/1998 7:05:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.01	<	0.01	<	0.01
7/15/1998 7:45:00 AM			<	0.5																
8/19/1998 5:50:00 AM			<	0.5																
9/16/1998 8:00:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.01	<	0.01	<	0.01
10/21/1998 6:25:00 AM			<	0.5																
11/18/1998 8:20:00 AM			<	0.5																
12/16/1998 8:55:00 AM			<	0.5																
1/20/1999 8:25:00 AM			<	0.5																
2/17/1999 7:30:00 AM			<	0.5																
3/17/1999 8:40:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.01	<	0.01	<	0.01
4/21/1999 7:13:00 AM			<	0.5																
5/19/1999 7:20:00 AM			<	0.5																
6/16/1999 8:00:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.01	<	0.01	<	0.01
7/21/1999 7:30:00 AM			<	0.5																
8/18/1999 6:35:00 AM			<	0.5																
9/15/1999 9:55:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.1	<	0.1	<	0.1
10/20/1999 6:45:00 AM			<	0.5																
11/17/1999 7:25:00 AM			<	0.5																
12/15/1999 6:50:00 AM			<	0.5																
1/19/2000 8:20:00 AM			<	0.5																
2/16/2000 8:20:00 AM			<	0.5																
3/15/2000 8:25:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.1	<	0.1	<	0.1
4/19/2000 6:30:00 AM			<	0.5																
5/17/2000 6:40:00 AM			<	0.5																
6/21/2000 6:50:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.01	<	0.01	<	0.01
7/19/2000 8:40:00 AM			<	0.5																
8/16/2000 6:45:00 AM			<	0.5																
9/20/2000 7:30:00 AM			<	0.5																
10/18/2000 6:50:00 AM			<	0.5																
11/15/2000 8:05:00 AM			<	0.5																
12/20/2000 9:50:00 AM			<	0.5																
12/27/2000 9:00:00 AM																				
1/10/2001 8:55:48 AM																				
1/10/2001 9:00:00 AM																				
1/10/2001 9:05:48 AM																				
1/17/2001 9:45:11 AM																				
2/15/2001 11:35:00 AM																				
2/15/2001 11:43:00 AM																				
2/16/2001 10:55:00 AM																				
2/16/2001 11:33:00 AM																				
2/21/2001 8:05:16 AM			<	0.5																
8/21/2002 5:19:06 AM			<	0.5																
9/18/2002 5:00:00 AM	<	0.2	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.1	<	0.1	<	0.1
12/18/2002 6:12:00 AM			<	0.5																
9/17/2003 7:40:00 AM	<	0.1	<	0.5	<	0.01	<	0.01	<	0.05	<	0.01	<	0.01	<	0.1	<	0.1	<	0.1
9/17/2003 7:45:00 AM																				
10/15/2003 7:50:00 AM			<	0.5																
11/19/2003 7:40:00 AM																				
12/17/2003 7:20:00 AM																				
12/17/2003 7:25:00 AM																				
1/21/2004 8:20:00 AM			<	0.5																
count		10		50		10		10		10		10		10		10		10		10
# NDs		10		50		10		10		10		10		10		10		10		10
average		0.19		0.50		0.01		0.01		0.05		0.01		0.01		0.05		0.05		0.05
stand dev		0.03		0		0		0		0		0		0		0		0		0

Attachment 2. Banks Pump

Collection Date	PCB-1242	PCB-1248	PCB-1254	PCB-1260	PCB's	Pendimethalin	Pentachloronitrobenzene (PCNB)	Pentachlorophenol (PCP)
6/22/1995 9:55:00 AM								
7/20/1995 10:38:00 AM								
8/17/1995 9:15:00 AM								
9/14/1995 9:43:00 AM								
10/19/1995 10:30:00 AM								
11/16/1995 11:00:00 AM								
12/7/1995 11:47:00 AM					< 0.2			< 0.2
1/18/1996 11:42:00 AM								
2/15/1996 11:24:00 AM								
3/14/1996 12:35:00 PM					< 0.2			< 0.2
4/11/1996 10:26:00 AM								
5/9/1996 10:40:00 AM								
6/13/1996 12:25:00 PM					< 0.2			< 0.2
7/18/1996 12:20:00 PM								
8/15/1996 9:51:00 AM								
9/12/1996 12:30:00 PM					< 0.2			< 0.2
10/10/1996 9:53:00 AM								
11/14/1996 12:35:00 PM								
12/12/1996 12:45:00 PM					< 0.2			< 0.2
1/7/1997 2:08:00 PM								
2/13/1997 11:20:00 AM								
3/13/1997 12:30:00 PM								
4/9/1997 10:50:00 AM								
5/13/1997 11:15:00 AM								
6/4/1997 9:28:00 AM								
7/2/1997 12:30:00 PM								
12/17/1997 9:50:00 AM								
1/21/1998 9:00:00 AM								
2/18/1998 8:20:00 AM								
3/18/1998 8:50:00 AM	< 0.01	< 0.01	< 0.01	< 0.01		< 5	< 0.01	< 0.1
4/15/1998 6:30:00 AM								
5/20/1998 6:00:00 AM								
6/17/1998 7:05:00 AM	< 0.01	< 0.01	< 0.01	< 0.01		< 5	< 0.01	< 0.1
7/15/1998 7:45:00 AM								
8/19/1998 5:50:00 AM								
9/16/1998 8:00:00 AM	< 0.01	< 0.01	< 0.01	< 0.01		< 5	< 0.01	< 0.1
10/21/1998 6:25:00 AM								
11/18/1998 8:20:00 AM								
12/16/1998 8:55:00 AM								
1/20/1999 8:25:00 AM								
2/17/1999 7:30:00 AM								
3/17/1999 8:40:00 AM	< 0.01	< 0.01	< 0.01	< 0.01		< 5	< 0.01	< 0.1
4/21/1999 7:13:00 AM								
5/19/1999 7:20:00 AM								
6/16/1999 8:00:00 AM	< 0.01	< 0.01	< 0.01	< 0.01		< 5	< 0.01	< 0.1
7/21/1999 7:30:00 AM								
8/18/1999 6:35:00 AM								
9/15/1999 9:55:00 AM	< 0.1	< 0.1	< 0.1	< 0.1		< 5	< 0.01	< 0.1
10/20/1999 6:45:00 AM								
11/17/1999 7:25:00 AM								
12/15/1999 6:50:00 AM								
1/19/2000 8:20:00 AM								
2/16/2000 8:20:00 AM								
3/15/2000 8:25:00 AM	< 0.1	< 0.1	< 0.1	< 0.1		< 5	< 0.01	< 0.1
4/19/2000 6:30:00 AM								
5/17/2000 6:40:00 AM								
6/21/2000 6:50:00 AM	< 0.01	< 0.01	< 0.01	< 0.01		< 5	< 0.01	< 0.1
7/19/2000 8:40:00 AM								
8/16/2000 6:45:00 AM								
9/20/2000 7:30:00 AM								
10/18/2000 6:50:00 AM								
11/15/2000 8:05:00 AM								
12/20/2000 9:50:00 AM								
12/27/2000 9:00:00 AM								
1/10/2001 8:55:48 AM								
1/10/2001 9:00:00 AM								
1/10/2001 9:05:48 AM								
1/17/2001 9:45:11 AM								
2/15/2001 11:35:00 AM								
2/15/2001 11:43:00 AM								
2/16/2001 10:55:00 AM								
2/16/2001 11:33:00 AM								
2/21/2001 8:05:16 AM								
8/21/2002 5:19:06 AM								
9/18/2002 5:00:00 AM	< 0.1	< 0.1	< 0.1	< 0.1		< 5	< 0.01	< 0.1
12/18/2002 6:12:00 AM								
9/17/2003 7:40:00 AM	< 0.1	< 0.1	< 0.1	< 0.1		< 0.05	< 0.01	< 0.1
9/17/2003 7:45:00 AM								
10/15/2003 7:50:00 AM								
11/19/2003 7:40:00 AM								
12/17/2003 7:20:00 AM								
12/17/2003 7:25:00 AM								
1/21/2004 8:20:00 AM								
count	10	10	10	10	5	10	10	15
# NDs	10	10	10	10	5	10	10	15
average	0.05	0.05	0.05	0.05	0.20	4.51	0.01	0.13
stand dev	0	0	0	0	0	1.6	0	0

Attachment 2. Banks Pump

Collection Date	Permethrin	Phorate	Phosalone	Phosmet	Picloram	Profenofos	Prometryn	Propachlor	Propanil	Propargite	Propetamphos
6/22/1995 9:55:00 AM											
7/20/1995 10:38:00 AM											
8/17/1995 9:15:00 AM											
9/14/1995 9:43:00 AM											
10/19/1995 10:30:00 AM											
11/16/1995 11:00:00 AM											
12/7/1995 11:47:00 AM					< 0.1		< 2	< 0.5			
1/18/1996 11:42:00 AM											
2/15/1996 11:24:00 AM											
3/14/1996 12:35:00 PM					< 0.1		< 2	< 0.5			
4/11/1996 10:26:00 AM											
5/9/1996 10:40:00 AM											
6/13/1996 12:25:00 PM					< 0.1		< 2	< 0.5			
7/18/1996 12:20:00 PM											
8/15/1996 9:51:00 AM											
9/12/1996 12:30:00 PM					< 0.1		< 2	< 0.5			
10/10/1996 9:53:00 AM											
11/14/1996 12:35:00 PM											
12/12/1996 12:45:00 PM					< 0.1		< 2	< 0.5			
1/7/1997 2:08:00 PM											
2/13/1997 11:20:00 AM											
3/13/1997 12:30:00 PM											
4/9/1997 10:50:00 AM											
5/13/1997 11:15:00 AM											
6/4/1997 9:28:00 AM											
7/2/1997 12:30:00 PM											
12/17/1997 9:50:00 AM											
1/21/1998 9:00:00 AM											
2/18/1998 8:20:00 AM											
3/18/1998 8:50:00 AM		< 0.01	< 0.02	< 0.02	< 1	< 0.01	< 0.05			< 1	< 0.1
4/15/1998 6:30:00 AM											
5/20/1998 6:00:00 AM											
6/17/1998 7:05:00 AM		< 0.01	< 0.02	< 0.02	< 1	< 0.01	< 0.05			< 1	< 0.1
7/15/1998 7:45:00 AM											
8/19/1998 5:50:00 AM											
9/16/1998 8:00:00 AM		< 0.01	< 0.02	< 0.02	< 1	< 0.01	< 0.05			< 1	< 0.1
10/21/1998 6:25:00 AM											
11/18/1998 8:20:00 AM											
12/16/1998 8:55:00 AM											
1/20/1999 8:25:00 AM											
2/17/1999 7:30:00 AM											
3/17/1999 8:40:00 AM		< 0.01	< 0.02	< 0.02	< 1	< 0.01	< 0.05			< 1	< 0.1
4/21/1999 7:13:00 AM											
5/19/1999 7:20:00 AM											
6/16/1999 8:00:00 AM		< 0.01	< 0.02	< 0.02	< 1	< 0.01	< 0.05			< 1	< 0.1
7/21/1999 7:30:00 AM											
8/18/1999 6:35:00 AM											
9/15/1999 9:55:00 AM		< 0.01	< 0.02	< 0.02	< 1	< 0.01	< 0.05			< 1	< 0.1
10/20/1999 6:45:00 AM											
11/17/1999 7:25:00 AM											
12/15/1999 6:50:00 AM											
1/19/2000 8:20:00 AM											
2/16/2000 8:20:00 AM											
3/15/2000 8:25:00 AM		< 0.01	< 0.02	< 0.02	< 0.1	< 0.01	< 0.05			< 1	< 0.1
4/19/2000 6:30:00 AM											
5/17/2000 6:40:00 AM											
6/21/2000 6:50:00 AM		< 0.01	< 0.02	< 0.02	< 0.1	< 0.01	< 0.05			< 1	< 0.1
7/19/2000 8:40:00 AM											
8/16/2000 6:45:00 AM											
9/20/2000 7:30:00 AM											
10/18/2000 6:50:00 AM											
11/15/2000 8:05:00 AM											
12/20/2000 9:50:00 AM											
12/27/2000 9:00:00 AM											
1/10/2001 8:55:48 AM											
1/10/2001 9:00:00 AM											
1/10/2001 9:05:48 AM											
1/17/2001 9:45:11 AM											
2/15/2001 11:35:00 AM											
2/15/2001 11:43:00 AM											
2/16/2001 10:55:00 AM											
2/16/2001 11:33:00 AM											
2/21/2001 8:05:16 AM											
8/21/2002 5:19:06 AM											
9/18/2002 5:00:00 AM		< 0.01	< 0.02	< 0.02	< 0.1	< 0.01	< 0.05			< 1	< 0.1
12/18/2002 6:12:00 AM											
9/17/2003 7:40:00 AM	< 0.02	< 0.01	< 0.02	< 0.02	< 0.1	< 0.01	< 0.05			< 1	< 0.1
9/17/2003 7:45:00 AM											
10/15/2003 7:50:00 AM											
11/19/2003 7:40:00 AM											
12/17/2003 7:20:00 AM											
12/17/2003 7:25:00 AM											
1/21/2004 8:20:00 AM											
count	1	10	10	10	15	10	15	5		10	10
# NDs	1	10	10	10	15	10	15	5		10	10
average	0.02	0.01	0.02	0.02	0.46	0.01	0.70	0.50		1.00	0.10
stand dev		0	0	0	0	0	1.0	0		0	0

Attachment 2. Banks Pump

Collection Date	Propham		p-Xylene		s,s,s-Tributyl Phosphorotrithioate (DEF)		sec-Butylbenzene		Simazine		Styrene		tert-Butylbenzene		Tetrachloroethene
6/22/1995 9:55:00 AM															
7/20/1995 10:38:00 AM															
8/17/1995 9:15:00 AM															
9/14/1995 9:43:00 AM															
10/19/1995 10:30:00 AM															
11/16/1995 11:00:00 AM															
12/7/1995 11:47:00 AM		<	0.5			<	0.5	<	1	<	0.5	<	0.5	<	0.5
1/18/1996 11:42:00 AM															
2/15/1996 11:24:00 AM															
3/14/1996 12:35:00 PM								<	1						
4/11/1996 10:26:00 AM															
5/9/1996 10:40:00 AM															
6/13/1996 12:25:00 PM		<	0.5			<	0.5	<	1	<	0.5	<	0.5	<	0.5
7/18/1996 12:20:00 PM															
8/15/1996 9:51:00 AM															
9/12/1996 12:30:00 PM		<	0.5			<	0.5	<	1	<	0.5	<	0.5	<	0.5
10/10/1996 9:53:00 AM															
11/14/1996 12:35:00 PM															
12/12/1996 12:45:00 PM		<	0.5			<	0.5	<	1	<	0.5	<	0.5	<	0.5
1/7/1997 2:08:00 PM															
2/13/1997 11:20:00 AM															
3/13/1997 12:30:00 PM															
4/9/1997 10:50:00 AM		<	0.5			<	0.5	<		<	0.5	<	0.5	<	0.5
5/13/1997 11:15:00 AM		<	0.5			<	0.5	<		<	0.5	<	0.5	<	0.5
6/4/1997 9:28:00 AM															
7/2/1997 12:30:00 PM		<	0.5			<	0.5	<		<	0.5	<	0.5	<	0.5
12/17/1997 9:50:00 AM		<	0.5			<	0.5	<		<	0.5	<	0.5	<	0.5
1/21/1998 9:00:00 AM															
2/18/1998 8:20:00 AM		<	0.5			<	0.5			<	0.5	<	0.5	<	0.5
3/18/1998 8:50:00 AM		<	0.5	<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
4/15/1998 6:30:00 AM		<	0.5			<	0.5			<	0.5	<	0.5	<	0.5
5/20/1998 6:00:00 AM		<	0.5			<	0.5			<	0.5	<	0.5	<	0.5
6/17/1998 7:05:00 AM		<	0.5	<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
7/15/1998 7:45:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
8/19/1998 5:50:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
9/16/1998 8:00:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
10/21/1998 6:25:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
11/18/1998 8:20:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
12/16/1998 8:55:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
1/20/1999 8:25:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
2/17/1999 7:30:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
3/17/1999 8:40:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
4/21/1999 7:13:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
5/19/1999 7:20:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
6/16/1999 8:00:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
7/21/1999 7:30:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
8/18/1999 6:35:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
9/15/1999 9:55:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
10/20/1999 6:45:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
11/17/1999 7:25:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
12/15/1999 6:50:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
1/19/2000 8:20:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
2/16/2000 8:20:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
3/15/2000 8:25:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
4/19/2000 6:30:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
5/17/2000 6:40:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
6/21/2000 6:50:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
7/19/2000 8:40:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
8/16/2000 6:45:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
9/20/2000 7:30:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
10/18/2000 6:50:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
11/15/2000 8:05:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
12/20/2000 9:50:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
12/27/2000 9:00:00 AM															
1/10/2001 8:55:48 AM															
1/10/2001 9:00:00 AM															
1/10/2001 9:05:48 AM															
1/17/2001 9:45:11 AM															
2/15/2001 11:35:00 AM															
2/15/2001 11:43:00 AM															
2/16/2001 10:55:00 AM															
2/16/2001 11:33:00 AM															
2/21/2001 8:05:16 AM						<	0.5			<	0.5	<	0.5	<	0.5
8/21/2002 5:19:06 AM						<	0.5			<	0.5	<	0.5	<	0.5
9/18/2002 5:00:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
12/18/2002 6:12:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
9/17/2003 7:40:00 AM				<	0.01	<	0.5	<	0.02	<	0.5	<	0.5	<	0.5
9/17/2003 7:45:00 AM															
10/15/2003 7:50:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
11/19/2003 7:40:00 AM															
12/17/2003 7:20:00 AM															
12/17/2003 7:25:00 AM															
1/21/2004 8:20:00 AM						<	0.5			<	0.5	<	0.5	<	0.5
count			13		10		50		15		50		50		50
# NDs			13		10		50		19		50		50		50
average			0.50		0.01		0.50		0.35		0.50		0.50		0.50
stand dev			0		0		0		0		0		0		0

Attachment 2. Banks Pump

Collection Date	Thiobencarb	Toluene	Toxaphene	trans-1,2-Dichloroethene	trans-1,3-Dichloropropene	Trichloroacetic Acid (TCAA)	Trichloroacetonitrile
6/22/1995 9:55:00 AM							
7/20/1995 10:38:00 AM							
8/17/1995 9:15:00 AM							
9/14/1995 9:43:00 AM							
10/19/1995 10:30:00 AM							
11/16/1995 11:00:00 AM							
12/7/1995 11:47:00 AM	< 1	< 0.5	< 0.5	< 0.5	< 0.5		< 1.00
1/18/1996 11:42:00 AM							
2/15/1996 11:24:00 AM							
3/14/1996 12:35:00 PM	< 1		< 0.5				< 1.00
4/11/1996 10:26:00 AM						37	
5/9/1996 10:40:00 AM						23	
6/13/1996 12:25:00 PM	< 1	< 0.5	< 0.5	< 0.5	< 0.5	20	< 1.00
7/18/1996 12:20:00 PM						26	
8/15/1996 9:51:00 AM						36	
9/12/1996 12:30:00 PM	< 1	< 0.5	< 1	< 0.5	< 0.5	19	< 1.00
10/10/1996 9:53:00 AM						44	
11/14/1996 12:35:00 PM						17	
12/12/1996 12:45:00 PM	< 1	< 0.5	< 1	< 0.5	< 0.5	44	< 1.00
1/7/1997 2:08:00 PM						65	
2/13/1997 11:20:00 AM						63	
3/13/1997 12:30:00 PM						53	
4/9/1997 10:50:00 AM	<	< 0.5		< 0.5	< 0.5	58	
5/13/1997 11:15:00 AM	<	< 0.5		< 0.5	< 0.5	20	
6/4/1997 9:28:00 AM						24	
7/2/1997 12:30:00 PM	<	< 0.5		< 0.5	< 0.5	23	
12/17/1997 9:50:00 AM	<	< 0.5		< 0.5	< 0.5		
1/21/1998 9:00:00 AM							
2/18/1998 8:20:00 AM		< 0.5		< 0.5	< 0.5	90	
3/18/1998 8:50:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5	72	
4/15/1998 6:30:00 AM		< 0.5		< 0.5	< 0.5	53	
5/20/1998 6:00:00 AM		< 0.5		< 0.5	< 0.5	57	
6/17/1998 7:05:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5	49	
7/15/1998 7:45:00 AM		< 0.5		< 0.5	< 0.5	41	
8/19/1998 5:50:00 AM		< 0.5		< 0.5	< 0.5	49	
9/16/1998 8:00:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5	53	
10/21/1998 6:25:00 AM		< 0.5		< 0.5	< 0.5	38	
11/18/1998 8:20:00 AM		< 0.5		< 0.5	< 0.5	68	
12/16/1998 8:55:00 AM		< 0.5		< 0.5	< 0.5	43	
1/20/1999 8:25:00 AM		< 0.5		< 0.5	< 0.5	64	
2/17/1999 7:30:00 AM		< 0.5		< 0.5	< 0.5	127	
3/17/1999 8:40:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5	40	
4/21/1999 7:13:00 AM		< 0.5		< 0.5	< 0.5	63	
5/19/1999 7:20:00 AM		< 0.5		< 0.5	< 0.5	46	
6/16/1999 8:00:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5	43	
7/21/1999 7:30:00 AM		< 0.5		< 0.5	< 0.5	53	
8/18/1999 6:35:00 AM		< 0.5		< 0.5	< 0.5		
9/15/1999 9:55:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5		
10/20/1999 6:45:00 AM		< 0.5		< 0.5	< 0.5		
11/17/1999 7:25:00 AM		< 0.5		< 0.5	< 0.5		
12/15/1999 6:50:00 AM		< 0.5		< 0.5	< 0.5		
1/19/2000 8:20:00 AM		< 0.5		< 0.5	< 0.5		
2/16/2000 8:20:00 AM		< 0.5		< 0.5	< 0.5		
3/15/2000 8:25:00 AM	< 0.02	< 0.5	< 1	< 0.5	< 0.5		
4/19/2000 6:30:00 AM		< 0.5		< 0.5	< 0.5		
5/17/2000 6:40:00 AM		< 0.5		< 0.5	< 0.5		
6/21/2000 6:50:00 AM	< 0.02	< 0.5	< 0.4	< 0.5	< 0.5		
7/19/2000 8:40:00 AM		< 0.5		< 0.5	< 0.5		
8/16/2000 6:45:00 AM		< 0.5		< 0.5	< 0.5		
9/20/2000 7:30:00 AM		< 0.5		< 0.5	< 0.5		
10/18/2000 6:50:00 AM		< 0.5		< 0.5	< 0.5		
11/15/2000 8:05:00 AM		< 0.5		< 0.5	< 0.5		
12/20/2000 9:50:00 AM		< 0.5		< 0.5	< 0.5		
12/27/2000 9:00:00 AM							
1/10/2001 8:55:48 AM							
1/10/2001 9:00:00 AM							
1/10/2001 9:05:48 AM							
1/17/2001 9:45:11 AM							
2/15/2001 11:35:00 AM							
2/15/2001 11:43:00 AM							
2/16/2001 10:55:00 AM							
2/16/2001 11:33:00 AM							
2/21/2001 8:05:16 AM		< 0.5		< 0.5	< 0.5		
8/21/2002 5:19:06 AM		< 0.5		< 0.5	< 0.5		
9/18/2002 5:00:00 AM	< 0.02	< 0.5	< 0.4	< 0.5	< 0.5		
12/18/2002 6:12:00 AM		< 0.5		< 0.5	< 0.5		
9/17/2003 7:40:00 AM	< 0.02	< 0.5	< 0.4	< 0.5	< 0.5		
9/17/2003 7:45:00 AM							
10/15/2003 7:50:00 AM		< 0.5		< 0.5	< 0.5		
11/19/2003 7:40:00 AM							
12/17/2003 7:20:00 AM							
12/17/2003 7:25:00 AM							
1/21/2004 8:20:00 AM		< 0.5		< 0.5	< 0.5		
count	15	50	15	50	50	34	5
# NDs	19	50	15	50	50	0	5
average	0.35	0.50	0.78	0.50	0.50	47.68	1.00
stand dev	0	0	0	0	0	22	0

Attachment 2. Banks Pump

Collection Date		Trichloroethene		Trichlorofluoromethane		Triclopyr		Trifluralin		Vinyl chloride
6/22/1995 9:55:00 AM										
7/20/1995 10:38:00 AM										
8/17/1995 9:15:00 AM										
9/14/1995 9:43:00 AM										
10/19/1995 10:30:00 AM										
11/16/1995 11:00:00 AM										
12/7/1995 11:47:00 AM			<	0.5			<	5	<	0.5
1/18/1996 11:42:00 AM										
2/15/1996 11:24:00 AM										
3/14/1996 12:35:00 PM								5		
4/11/1996 10:26:00 AM										
5/9/1996 10:40:00 AM										
6/13/1996 12:25:00 PM			<	0.5			<	5	<	0.5
7/18/1996 12:20:00 PM										
8/15/1996 9:51:00 AM										
9/12/1996 12:30:00 PM	<	0.5	<	0.5			<	5		
10/10/1996 9:53:00 AM										
11/14/1996 12:35:00 PM										
12/12/1996 12:45:00 PM	<	0.5	<	0.5			<	5		
1/7/1997 2:08:00 PM										
2/13/1997 11:20:00 AM										
3/13/1997 12:30:00 PM										
4/9/1997 10:50:00 AM	<	0.5	<	0.5					<	0.5
5/13/1997 11:15:00 AM			<	0.5					<	0.5
6/4/1997 9:28:00 AM										
7/2/1997 12:30:00 PM	<	0.5	<	0.5					<	0.5
12/17/1997 9:50:00 AM	<	0.5	<	0.5					<	0.5
1/21/1998 9:00:00 AM										
2/18/1998 8:20:00 AM	<	0.5	<	0.5					<	0.5
3/18/1998 8:50:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
4/15/1998 6:30:00 AM	<	0.5	<	0.5					<	0.5
5/20/1998 6:00:00 AM	<	0.5	<	0.5					<	0.5
6/17/1998 7:05:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
7/15/1998 7:45:00 AM	<	0.5	<	0.5					<	0.5
8/19/1998 5:50:00 AM	<	0.5	<	0.5					<	0.5
9/16/1998 8:00:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
10/21/1998 6:25:00 AM	<	0.5	<	0.5					<	0.5
11/18/1998 8:20:00 AM	<	0.5	<	0.5					<	0.5
12/16/1998 8:55:00 AM	<	0.5	<	0.5					<	0.5
1/20/1999 8:25:00 AM	<	0.5	<	0.5					<	0.5
2/17/1999 7:30:00 AM	<	0.5	<	0.5					<	0.5
3/17/1999 8:40:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
4/21/1999 7:13:00 AM	<	0.5	<	0.5					<	0.5
5/19/1999 7:20:00 AM	<	0.5	<	0.5					<	0.5
6/16/1999 8:00:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
7/21/1999 7:30:00 AM	<	0.5	<	0.5					<	0.5
8/18/1999 6:35:00 AM	<	0.5	<	0.5					<	0.5
9/15/1999 9:55:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
10/20/1999 6:45:00 AM	<	0.5	<	0.5					<	0.5
11/17/1999 7:25:00 AM	<	0.5	<	0.5					<	0.5
12/15/1999 6:50:00 AM	<	0.5	<	0.5					<	0.5
1/19/2000 8:20:00 AM	<	0.5	<	0.5					<	0.5
2/16/2000 8:20:00 AM	<	0.5	<	0.5					<	0.5
3/15/2000 8:25:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
4/19/2000 6:30:00 AM	<	0.5	<	0.5					<	0.5
5/17/2000 6:40:00 AM	<	0.5	<	0.5					<	0.5
6/21/2000 6:50:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
7/19/2000 8:40:00 AM	<	0.5	<	0.5					<	0.5
8/16/2000 6:45:00 AM	<	0.5	<	0.5					<	0.5
9/20/2000 7:30:00 AM	<	0.5	<	0.5					<	0.5
10/18/2000 6:50:00 AM	<	0.5	<	0.5					<	0.5
11/15/2000 8:05:00 AM	<	0.5	<	0.5					<	0.5
12/20/2000 9:50:00 AM	<	0.5	<	0.5					<	0.5
12/27/2000 9:00:00 AM										
1/10/2001 8:55:48 AM										
1/10/2001 9:00:00 AM										
1/10/2001 9:05:48 AM										
1/17/2001 9:45:11 AM										
2/15/2001 11:35:00 AM										
2/15/2001 11:43:00 AM										
2/16/2001 10:55:00 AM										
2/16/2001 11:33:00 AM										
2/21/2001 8:05:16 AM	<	0.5	<	0.5					<	0.5
8/21/2002 5:19:06 AM	<	0.5	<	0.5					<	0.5
9/18/2002 5:00:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
12/18/2002 6:12:00 AM	<	0.5	<	0.5					<	0.5
9/17/2003 7:40:00 AM	<	0.5	<	0.5	<	0.1	<	0.01	<	0.5
9/17/2003 7:45:00 AM										
10/15/2003 7:50:00 AM	<	0.5	<	0.5					<	0.5
11/19/2003 7:40:00 AM										
12/17/2003 7:20:00 AM										
12/17/2003 7:25:00 AM										
1/21/2004 8:20:00 AM	<	0.5	<	0.5					<	0.5
count		47		50		10		15		48
# NDs		47		50		10		14		48
average		0.50		0.50		0.10		1.67		0.50
stand dev		0		0		0		2.4		0

Attachment 2. Banks Pumping Plant at California Aquaduct (all results in ug/L)

Collection Date		Bromodichloromethane		Bromoform		Chloroform		Dibromochloromethane
1/24/1990 9:20:00 AM		160		20		240		110
2/7/1990 10:34:00 AM								
2/14/1990 8:55:00 AM								
2/21/1990 9:21:00 AM		150		4		290		56
3/7/1990 10:50:00 AM								
3/20/1990 11:00:00 AM		110		3		310		45
4/4/1990 12:00:00 PM								
4/25/1990 8:00:00 AM		140		21		190		100
5/23/1990 10:35:00 AM		190		19		220		110
6/27/1990 9:15:00 AM		140				260		
7/9/1990 3:40:00 PM		160		6		390		73
7/16/1990 10:30:00 AM		150		4		440		54
7/26/1990 10:10:00 AM		90		4		220		49
7/30/1990 11:00:00 AM		130		5		290		64
8/6/1990 9:30:00 AM		170		5		406		72
8/13/1990 9:20:00 AM		150		6		300		73
8/22/1990 12:40:00 PM		140		3		320		56
8/27/1990 10:24:00 AM		170	<	1		730		133
9/4/1990 1:00:00 PM		140	<	1		350		52
9/10/1990 10:55:00 AM		160	<	1		350		67
9/18/1990 12:10:00 PM		160	<	1		380		59
9/24/1990 11:00:00 AM		160		5		270		74
10/2/1990 12:05:00 PM		150	<	1		300		66
10/10/1990 9:30:00 AM		190		8		260		100
10/16/1990 8:45:00 AM		170		11		240		10
10/24/1990 8:58:00 AM		200		13		300		120
10/30/1990 12:00:00 PM		400		38		420		270
11/13/1990 12:25:00 PM		150	<	1		190		100
11/27/1990 11:30:00 AM		160		20		180		130
12/11/1990 12:10:00 PM		180		24		240		160
1/2/1991 12:25:00 PM		250		18		410		160
1/15/1991 1:05:00 PM		260		7		630		120
1/29/1991 12:05:00 PM		280		12		520		160
2/13/1991 9:35:00 AM		400		26		740		240
2/27/1991 11:25:00 AM		510		46		780		330
3/11/1991 9:40:00 AM		430		40		590		300
3/27/1991 2:00:00 PM		400	<	5		1290		119
4/9/1991 10:18:00 AM		100	<	5		630		11
4/23/1991 8:20:00 AM		78	<	5		610		9.2
5/21/1991 10:50:00 AM		110	<	5		560		29
6/11/1991 9:50:00 AM		290	<	5		670		137
6/25/1991 12:50:00 PM		210		8.2		420		110
7/8/1991 8:22:00 AM		150		9		350		84
7/24/1991 7:38:00 AM		140		10		320		95
8/5/1991 8:30:00 AM		170		7.4		320		96
8/21/1991 7:19:00 AM		160		6.6		290		89
9/10/1991 8:30:00 AM		140		5.3		290		75
9/24/1991 8:30:00 AM		140		10		220		92
10/8/1991 8:05:00 AM		120		6.2		250		77
10/23/1991 7:35:00 AM		92		0		180		62
11/21/1991 11:15:00 AM		140		13		190		100

Attachment 2. Banks Pumping Plant at California Aquaduct (all results in ug/L)

Collection Date		Bromodichloromethane		Bromoform		Chloroform		Dibromochloromethane
12/11/1991 9:20:00 AM		290		35		380		208
1/7/1992 9:32:00 AM		170		12		380		93
1/23/1992 8:50:00 AM		310		5.9		880		135
2/4/1992 8:55:00 AM		170		7.4		310		98
2/25/1992 9:40:00 AM		280	<	5		1100		65
3/10/1992 10:43:00 AM		165	<	5		1190		18.4
3/26/1992 9:30:00 AM		67	<	5		510		6.9
4/7/1992 10:20:00 AM		77	<	5		430		11
4/22/1992 7:15:00 AM		184	<	5		1420		30
5/7/1992 9:02:00 AM		150	<	5		600		34
5/21/1992 8:43:00 AM		130	<	5		510		29
6/4/1992 9:15:00 AM		160	<	5		500		51
6/9/1992 8:48:00 AM		410	<	5		1040		168
6/25/1992 10:15:00 AM		270		7		360		170
7/7/1992 11:00:00 AM		200		10		300		140
7/22/1992 8:13:00 AM		180		28		180		130
8/4/1992 8:00:00 AM		160		21		180		150
8/19/1992 8:05:00 AM		140		15		180		110
9/1/1992 8:46:00 AM		140		12		160		110
9/24/1992 8:35:00 AM		120		11		150		95
10/7/1992 8:05:00 AM		140		11		160		96
10/19/1992 9:55:00 AM		110		9		110		73
11/19/1992 10:30:00 AM		140		10		160		98
12/10/1992 11:30:00 AM		140		7		190		98
1/13/1993 8:30:00 AM		110	<	5		460		17
1/26/1993 11:45:00 AM		110	<	5		1100		7
2/9/1993 11:45:00 AM		82	<	5		830	<	5
2/16/1993 10:30:00 AM		159	<	5		1580		10
3/9/1993 9:45:00 AM		96	<	5		700		8
3/25/1993 12:15:00 PM		62	<	5		440		6
4/8/1993 10:10:00 AM		88	<	5		390		15
4/21/1993 7:35:00 AM		70	<	5		310		9
5/13/1993 9:04:00 AM		88	<	5		320		23
6/10/1993 8:47:00 AM		72	<	5		230		21
7/8/1993 7:35:00 AM		111	<	5		630		16
7/20/1993 9:40:00 AM		40	<	5		300	<	5
8/10/1993 9:45:00 AM		35	<	5		240	<	5
9/1/1993 8:55:00 AM		42	<	5		280	<	5
9/21/1993 9:10:00 AM		49	<	5		210		8
10/14/1993 10:00:00 AM								
10/20/1993 8:25:00 AM		74	<	5		200		22
11/10/1993 10:50:00 AM		187	<	5		410		78
12/15/1993 8:40:00 AM		110	<	5		260		51
1/12/1994 10:20:00 AM		120	<	5		530		19
1/19/1994 11:15:00 AM		94	<	5		460		20
2/17/1994 10:40:00 AM		100	<	5		620		15
3/24/1994 10:15:00 AM		110	<	5		500		16
4/20/1994 9:10:00 AM		110	<	5		450		25
5/19/1994 9:28:00 AM		110	<	5		410		37
6/22/1994 10:20:00 AM		120	<	5		350		41
7/20/1994 9:45:00 AM		120	<	5		240		63

Attachment 2. Banks Pumping Plant at California Aquaduct (all results in ug/L)

Collection Date		Bromodichloromethane		Bromoform		Chloroform		Dibromochloromethane
8/25/1994 10:30:00 AM		150		6		290		83
9/22/1994 10:30:00 AM		191		22		260		164
10/20/1994 9:40:00 AM		110	<	5		180		64
11/17/1994 10:10:00 AM		140	<	5		260		47
12/20/1994 12:15:00 PM		120	<	5		250		49
1/26/1995 9:54:00 AM		56	<	5		640	<	5
2/16/1995 11:25:00 AM		82	<	5		580		10
3/20/1995 9:02:00 AM		110	<	5		450		27
4/24/1995 8:20:00 AM		92	<	5		430		17
5/18/1995 10:30:00 AM		42	<	5		360	<	5
6/22/1995 9:55:00 AM		58	<	5		310		10
7/20/1995 10:38:00 AM		38	<	5		380	<	10
8/17/1995 9:15:00 AM		110				290		37
9/14/1995 9:43:00 AM		42				260		
10/19/1995 10:30:00 AM		44	<	10		330	<	10
11/16/1995 11:00:00 AM		38	<	10		290	<	10
12/7/1995 11:47:00 AM		56	<	0.5		240	<	0.5
1/18/1996 11:42:00 AM		130	<	10		420		38
2/15/1996 11:24:00 AM		67	<	10		470	<	10
3/14/1996 12:35:00 PM		51	<	10		400	<	10
4/11/1996 10:26:00 AM		328		22		746		164
5/9/1996 10:40:00 AM		114		2		327		37
6/13/1996 12:25:00 PM		28	<	0.5		88		7
7/18/1996 12:20:00 PM		56	<	1		338		5
8/15/1996 9:51:00 AM		85	<	1		342		23
9/12/1996 12:30:00 PM		80	<	0.5		305		24
10/10/1996 9:53:00 AM		186		4		562		64
11/14/1996 12:35:00 PM		113		2		255		43
12/12/1996 12:45:00 PM		310		8		622		140
1/7/1997 2:08:00 PM		58	<	1		570		2
2/13/1997 11:20:00 AM		127	<	1		1210		5
3/13/1997 12:30:00 PM		87	<	1		446		7
4/9/1997 10:50:00 AM		220	<	0.5		882		27
5/13/1997 11:15:00 AM		150		3		442		48
6/4/1997 9:28:00 AM		137		1		436		36
7/2/1997 12:30:00 PM		124		12		360		54
12/17/1997 9:50:00 AM		160	<	0.5		300		88
1/21/1998 9:00:00 AM		120	<	10		440		30
2/18/1998 8:20:00 AM		207	<	0.5		740		54
3/18/1998 8:50:00 AM		203	<	0.5		760		50
4/15/1998 6:30:00 AM		262	<	0.5		610		123
5/20/1998 6:00:00 AM		145	<	0.5		580		34
6/17/1998 7:05:00 AM		82	<	0.5		510	<	0.5
7/15/1998 7:45:00 AM		56	<	0.5		500	<	0.5
8/19/1998 5:50:00 AM		85	<	0.5		520	<	0.5
9/16/1998 8:00:00 AM		94	<	0.5		470		12
10/21/1998 6:25:00 AM		76	<	0.5		410	<	0.5
11/18/1998 8:20:00 AM		101	<	0.5		460		13
12/16/1998 8:55:00 AM		154	<	0.5		380		74
1/20/1999 8:25:00 AM		190	<	0.5		690		59
2/17/1999 7:30:00 AM		161		16		610		54

Attachment 2. Banks Pumping Plant at California Aquaduct (all results in ug/L)

Collection Date		Bromodichloromethane		Bromoform		Chloroform		Dibromochloromethane
3/17/1999 8:40:00 AM		125	<	0.5		540		40
4/21/1999 7:13:00 AM		132		16		410		56
5/19/1999 7:20:00 AM		108	<	0.5		340		38
6/16/1999 8:00:00 AM		141	<	0.5		470		38
7/21/1999 7:30:00 AM		79	<	0.5		360	<	0.5
8/18/1999 6:35:00 AM		41	<	0.5		240	<	0.5
9/15/1999 9:55:00 AM		92	<	0.5		180		46
10/20/1999 6:45:00 AM		110		12		190		57
11/17/1999 7:25:00 AM		120		12		200		60
12/15/1999 6:50:00 AM		180		23		230		120
1/19/2000 8:20:00 AM		120	<	0.5		550		28
2/16/2000 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
3/15/2000 8:25:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
4/19/2000 6:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
5/17/2000 6:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
6/21/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
7/19/2000 8:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
8/16/2000 6:45:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
9/20/2000 7:30:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
10/18/2000 6:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
11/15/2000 8:05:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
12/20/2000 9:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
12/27/2000 9:00:00 AM								
1/10/2001 8:55:48 AM								
1/10/2001 9:00:00 AM								
1/10/2001 9:05:48 AM								
1/17/2001 9:45:11 AM								
2/15/2001 11:35:00 AM								
2/15/2001 11:43:00 AM								
2/16/2001 10:55:00 AM								
2/16/2001 11:33:00 AM								
2/21/2001 8:05:16 AM	<	0.5	<	0.5	<	0.5	<	0.5
8/21/2002 5:19:06 AM	<	0.5	<	0.5	<	0.5	<	0.5
9/18/2002 5:00:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
12/18/2002 6:12:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:40:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
9/17/2003 7:45:00 AM								
10/15/2003 7:50:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
11/19/2003 7:40:00 AM								
12/17/2003 7:20:00 AM								
12/17/2003 7:25:00 AM								
1/21/2004 8:20:00 AM	<	0.5	<	0.5	<	0.5	<	0.5
count		177		174		177		175
# NDs		18		109		18		36
average		129.4		6.60		389		56.2
stand dev		89		7.73		273		59.4

Attachment 3: Federal and State Maximum Contaminant Levels for Drinking Waters

(Source: CA Dept of Health Services, US EPA)

MAXIMUM CONTAMINANT LEVELS AND REGULATION DATES FOR DRINKING WATER CONTAMINANTS
USEPA VS CDHS
SEPTEMBER 2003

Contaminant	USEPA MCL (mg/L)	USEPA Date[a]	CDHS MCL (mg/L)	CDHS Effective Date
Inorganics				
Aluminum	0.05 to 2[b]	1/91	1 0.2[b]	2/25/89 9/8/94
Antimony	0.006	7/92	0.006	9/8/94
Arsenic	0.05 0.01	eff: 6/24/77 2001	0.05	77
Asbestos	7 MFL[c]	1/91	7 MFL[c]	9/8/94
Barium	1 2	eff: 6/24/77 1/91	1	77
Beryllium	0.004	7/92	0.004	9/8/94
Cadmium	0.010 0.005	eff: 6/24/77 1/91	0.010 0.005	77 9/8/94
Chromium	0.05 0.1	eff: 6/24/77 1/91	0.05	77
Copper	1.3[d]	6/91	1[b] 1.3[d]	77 12/11/95
Cyanide	0.2	7/92	0.2 0.15	9/8/94 6/12/03
Fluoride	4 2[b]	4/86 4/86	2	4/98
Lead	0.05[e] 0.015[d]	eff: 6/24/77 6/91	0.05[e] 0.015[d]	77 12/11/95
Mercury	0.002	eff: 6/24/77	0.002	77
Nickel	Remanded		0.1	9/8/94
Nitrate	(as N) 10	eff: 6/24/77	(as N03) 45	77
Nitrite (as N)	1	1/91	1	9/8/94
Total Nitrate/Nitrite (as N)	10	1/91	10	9/8/94
Selenium	0.01 0.05	eff: 6/24/77 1/91	0.01 0.05	77 9/8/94
Thallium	0.002	7/92	0.002	9/8/94
Radionuclides				
Uranium	30 ug/L	12/7/00	20 pCi/L	1/1/89
Combined radium-226 & 228	5 pCi/L	eff: 6/24/77	5 pCi/L	77
Gross Alpha particle activity	15 pCi/L	eff: 6/24/77	15 pCi/L	77
Gross Beta particle activity	dose of 4 millirem/yr	eff: 6/24/77	50 pCi/L[f]	77
Strontium-90	8 pCi/L	eff: 6/24/77 now covered by Gross Beta	8 pCi/L[f]	77
Tritium	20,000 pCi/L	eff: 6/24/77 now covered by Gross Beta	20,000 pCi/L[f]	77

Contaminant	USEPA MCL (mg/L)	USEPA Date[a]	CDHS MCL (mg/L)	CDHS Effective Date
VOCS				
Benzene	0.005	6/87	0.001	2/25/89
Carbon Tetrachloride	0.005	6/87	0.0005	4/4/89
1,2-Dichlorobenzene	0.6	1/91	0.6	9/8/94
1,4-Dichlorobenzene	0.075	6/87	0.005	4/4/89
1,1-Dichloroethane	-	-	0.005	6/24/90
1,2-Dichloroethane	0.005	6/87	0.0005	4/4/89
1,1-Dichloroethylene	0.007	6/87	0.006	2/25/89
cis-1,2-Dichloroethylene	0.07	1/91	0.006	9/8/94
trans-1,2-Dichloroethylene	0.1	1/91	0.01	9/8/94
Dichloromethane	0.005	7/92	0.005	9/8/94
1,3-Dichloropropene	-	-	0.0005	2/25/89
1,2-Dichloropropane	0.005	1/91	0.005	6/24/90
Ethylbenzene	0.7	1/91	0.68 0.7 0.3	2/25/89 9/8/94 6/12/03
Methyl-tert-butyl ether (MTBE)	-	-	0.005[b] 0.013	1/7/99 5/17/00
Monochlorobenzene	0.1	1/91	0.03 0.07	2/25/89 9/8/94
Styrene	0.1	1/91	0.1	9/8/94
1,1,2,2-Tetrachloroethane	-	-	0.001	2/25/89
Tetrachloroethylene	0.005	1/91	0.005	5/89
Toluene	1	1/91	0.15	9/8/94
1,2,4 Trichlorobenzene	0.07	7/92	0.07 0.005	9/8/94 6/12/03
1,1,1-Trichloroethane	0.200	6/87	0.200	2/25/89
1,1,2-Trichloroethane	0.005	7/92	0.032 0.005	4/4/89 9/8/94
Trichloroethylene	0.005	6/87	0.005	2/25/89
Trichlorofluoromethane	-	-	0.15	6/24/90
1,1,2-Trichloro-1,2,2-Trifluoroethane	-	-	1.2	6/24/90
Vinyl chloride	0.002	6/87	0.0005	4/4/89
Xylenes	10	1/91	1.750	2/25/89
SOCS				
Alachlor	0.002	1/91	0.002	9/8/94
Atrazine	0.003	1/91	0.003 0.001	4/5/89 6/12/03
Bentazon	-	-	0.018	4/4/89
Benzo(a) Pyrene	0.0002	7/92	0.0002	9/8/94
Carbofuran	0.04	1/91	0.018	6/24/90
Chlordane	0.002	1/91	0.0001	6/24/90
Dalapon	0.2	7/92	0.2	9/8/94
Dibromochloropropane	0.0002	1/91	0.0001 0.0002	7/26/89 5/3/91
Di(2-ethylhexyl)adipate	0.4	7/92	0.4	9/8/94
Di(2-ethylhexyl)phthalate	0.006	7/92	0.004	6/24/90
2,4-D	0.1 0.07	eff: 6/24/77 1/91	0.1 0.07	77 9/8/94
Dinoseb	0.007	7/92	0.007	9/8/94

Contaminant	USEPA MCL (mg/L)	USEPA Date[a]	CDHS MCL (mg/L)	CDHS Effective Date
Diquat	0.02	7/92	0.02	9/8/94
Endothall	0.1	7/92	0.1	9/8/94
Endrin	0.0002 0.002	eff: 6/24/77 7/92	0.0002 0.002	77 9/8/94
Ethylene Dibromide	0.00005	1/91	0.00002 0.00005	2/25/89 9/8/94
Glyphosate	0.7	7/92	0.7	6/24/90
Heptachlor	0.0004	1/91	0.00001	6/24/90
Heptachlor Epoxide	0.0002	1/91	0.00001	6/24/90
Hexachlorobenzene	0.001	7/92	0.001	9/8/94
Hexachlorocyclopentadiene	0.05	7/92	0.05	9/8/94
Lindane	0.004 0.0002	eff: 6/24/77 1/91	0.004 0.0002	77 9/8/94
Methoxychlor	0.1 0.04	eff: 6/24/77 1/91	0.1 0.04 0.03	77 9/8/94 6/12/03
Molinate	-	-	0.02	4/4/89
Oxamyl	0.2	7/92	0.2 0.05	9/8/94 6/12/03
Pentachlorophenol	0.001	1/91	0.001	9/8/94
Picloram	0.5	7/92	0.5	9/8/94
Polychlorinated Biphenyls	0.0005	1/91	0.0005	9/8/94
Simazine	0.004	7/92	0.010 0.004	4/4/89 9/8/94
Thiobencarb	-	-	0.07 0.001[b]	4/4/89 4/4/89
Toxaphene	0.005 0.003	eff: 6/24/77 1/91	0.005 0.003	77 9/8/94
2,3,7,8-TCDD (Dioxin)	$3x10^{-8}$	7/92	$3x10^{-8}$	9/8/94
2,4,5-TP (Silvex)	0.01 0.05	eff: 6/24/77 1/91	0.01 0.05	77 9/8/94
Disinfection Byproducts				
Total trihalomethanes	0.100 0.080	11/29/79 eff: 11/29/83 eff: 1/1/02 [g]	0.100	3/14/83
Total haloacetic acids	0.060	eff: 1/1/02 [g]		
Bromate	0.010	eff: 1/1/02 [g]		
Chlorite	1.0	eff: 1/1/02 [g]		
Treatment Technique				
Acrylamide	TT[h]	1/91	TT[h]	9/8/94
Epichlorohydrin	TT[h]	1/91	TT[h]	9/8/94

a. "eff." indicates the date the MCL took effect; any other date provided indicates when USEPA established (i.e., published) the MCL.
b. Secondary MCL.
c. MFL = million fibers per liter, with fiber length > 10 microns.
d. Regulatory Action Level; if system exceeds, it must take certain actions such as additional monitoring, corrosion control studies and treatment, and for lead, a public education program; replaces MCL.
e. The MCL for lead was rescinded with the adoption of the regulatory action level described in footnote d.
f. MCLs are intended to ensure that exposure above 4 millirem/yr does not occur.
g. Effective for surface water systems serving more than 10,000 people; effective for all others 1/1/04.
h. TT = treatment technique, because an MCL is not feasible.

Secondary Maximum Contaminant Levels

(Source: http://www.epa.gov/safewater/consumer/2ndstandards.html)

Contaminant	**Secondary MCL**	**Noticeable Effects above the Secondary MCL**
Aluminum	0.05 to 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Color	15 color units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
Odor	3 TON (threshold odor number)	"rotten-egg", musty or chemical smell
pH	6.5 - 8.5	*low pH:* bitter metallic taste; corrosion *high pH:* slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste
** mg/L is milligrams of substance per liter of water*		

APPENDIX C

Memorandum: Hetch Hetchy water and power issues

Prepared by Somach, Simmons & Dunn for Environmental Defense

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MEMORANDUM

To: Environmental Defense[*]

From: Stuart L. Somach[**]

Subject: Hetch Hetchy Water and Power Issues

Date: July, 2004

INTRODUCTION

I have reviewed materials available to me with respect to various questions that you have posed concerning the general water rights and entitlements of the City and County of San Francisco ("CCSF"). This review has been exclusive to CCSF's Tuolumne River water rights as they may derive from California law and the Raker Act.[1] It is my understanding that this information will be utilized by Environmental Defense, and perhaps others, in an analysis of water supply options and alternatives that CCSF may have available to it in lieu of its current storage of water in Hetch Hetchy Valley. As you are aware, I am a proponent of surface water storage as an essential element of what is needed to resolve California's water supply shortages and, in general, consider Hetch Hetchy a component in that overall water storage/supply picture. In this context, other than the legal opinions provided for herein, I offer no opinion with respect to options or alternatives to the storage of water in Hetch Hetchy Valley.

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* As you are aware, Somach, Simmons & Dunn represents the Turlock Irrigation District. At its request, I have provided this identical opinion to it pursuant to our attorney-client relationship.

** I have been assisted in the preparation of this Memorandum by Elizabeth W. Johnson, of the firm Wilkins, Underwood, Omstead & Johnson; and Nicholas A. Jacobs, an associate attorney with Somach, Simmons & Dunn.

1 Pub. L. No. 63-41 (Dec. 19, 1913) 38 Stats. 242.

QUESTIONS PRESENTED

1. Assuming that reasonable, feasible alternatives to utilizing existing or expanded Raker Act water supply facilities in the Hetch Hetchy Valley are available to CCSF, what legal considerations may require or encourage CCSF to consider such alternatives?

2. What legal factors affect the role Modesto Irrigation District and Turlock Irrigation District will have in CCSF's consideration of alternatives?

3. What legal factors affect the role of other agencies in CCSF's consideration of alternatives?

4. What legal requirements regarding hydroelectric power production may affect CCSF's decisions with respect to expansion and/or continued use of the facilities in the Hetch Hetchy Valley authorized by the Raker Act?

BRIEF ANSWERS

1. The California Water Plan assumes that water conservation and recycling, additional surface water storage in the greater Bay Area, desalinization, and reconfigured conveyance from the lower Tuolumne River and the San Francisco Bay-Delta may make water available to serve the region.[2] Assuming such alternatives are practical and available in the foreseeable future, and based on our research of this matter, the following legal considerations may require CCSF to consider diversions of Tuolumne River water elsewhere than from Hetch Hetchy Valley:

- CCSF has perfected water rights to about 300 million gallons per day ("mgd") from the Tuolumne River. Although CCSF has historically claimed a right as large as 400 mgd, these claims are undermined by the due diligence requirements of California water law, as well as by the effect of various terms or conditions in the Raker Act.

- CCSF's right to Tuolumne River water is a relative right. In this context, and by way of example, the Raker Act is very protective of the rights of the Turlock Irrigation District ("TID") and Modesto Irrigation District ("MID"). (TID and MID are referred to collectively as the "Districts.") The Raker Act protections, however, are limited to the Districts and may not be exercised by others. Further, California law prohibits exercise of CCSF's rights, existing or expanded, in a manner that injures the Districts or other senior water right holders.

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[2] California Water Plan, DWR Bulletin 160-04 (Draft), Vol. 3, Ch. 3.

- The Raker Act required CCSF to fully develop its other water resources before taking additional water from Hetch Hetchy. Today this may include greater use of recycled water and other alternative local sources.

2. The Districts hold water rights that are senior to CCSF's. Further, CCSF's rights and obligations with respect to "storage" in New Don Pedro Reservoir are governed by its agreement with the Districts. Without that agreement and its integration into various water rights and the Districts' Federal Energy Regulatory Commission ("FERC") licenses, CCSF would have no rights in New Don Pedro Reservoir. The Raker Act protections identified above give the Districts additional power to restrict CCSF's expansion of its Hetch Hetchy facilities.

3. The discretionary expansion of CCSF's system, or changes in the current diversion levels using existing facilities, would require an analysis of alternatives pursuant to the National Environmental Policy Act ("NEPA") and the California Environmental Quality Act ("CEQA"). It would, however, also require an analysis of the appropriateness of an upstream diversion within Yosemite National Park in light of the California public trust doctrine and of California's constitutional mandate to maximize the reasonable, beneficial use of water. Various agencies and the courts may assert oversight under these doctrines and environmental protection statutes. Public trust interests and the constitutional obligation to maximize the reasonable, beneficial use of California water are presumably constant limitations on CCSF's use of Tuolumne River water, whether existing or expanded.

4. The Raker Act explicitly requires CCSF to "develop and use hydroelectric power for the use of its people …." The Raker Act specifies the following priority of use of Hetch Hetchy power: (i) first, for CCSF's "actual municipal purposes;" (ii) second, to the Districts for "pumping subsurface water for drainage or irrigation" or for "actual municipal purposes;" and (iii) third, for commercial purposes, including sales to CCSF's residents and to "a municipality or a municipal water district or irrigation district" for resale but not to any corporation or individual for resale. CCSF's requirement to produce power for public purposes is a condition of the right-of-way granted by the Raker Act; accordingly, if it desires to continue to utilize those rights-of-way, it must continue to produce such power from facilities remaining in the Park.

DISCUSSION

Water rights are relative rights with their value, at least in part, dependent upon their relative priority with respect to those who also claim rights to divert and use water within the same river or stream system. As a consequence, it is both accurate to state that an individual or entity has a right to X million gallons per day or acre feet annually and also state that the exercise of that right to X million gallons per day or acre feet annually is conditioned on not injuring or impairing a more senior water right holder's ability to first divert and use its entitlement.

In this context, CCSF's right to water is and always has been tied to the rights of TID and MID and, to a lesser degree, others on the Tuolumne River. It is almost impossible to evaluate CCSF's water rights without reference to the water rights of the Districts. As a consequence, those references exist in the discussion that follows. Moreover, as a general comment, and consistent with this concept, modification of points of storage and diversion and storage for the exercise of CCSF's water rights would need to contemplate the rights of others, and modifications that injure or impair the rights of third parties would not be permitted absent compensation or mitigation. Accordingly, following is an analysis of CCSF's Hetch Hetchy water rights, including CCSF's claims regarding the scope of its rights and possible restrictions on those claims.

I.
THE INFRASTRUCTURE OF THE TUOLUMNE RIVER DEVELOPMENT

CCSF holds its water rights pursuant to California law. However, authorization to build its reservoirs on federal land and to obtain federal rights-of-way required an act of Congress, the Raker Act, passed in 1913.[3] Pursuant to this authority, CCSF constructed three storage reservoirs: O'Shaughnessy (capacity 360,400 acre feet) (1923 and enlarged in 1938) and Eleanor (capacity 27,100 acre feet) (1917) in Yosemite National Park; and Cherry Valley (capacity 268,800 acre feet) (1956) in Stanislaus National Forest. These reservoirs are the heart of the CCSF system[4] and are located on or tributary to the Tuolumne River. Releases from these facilities are the only source of water in the Tuolumne River upstream of the South Fork, and CCSF is solely responsible for maintaining flows in this stretch of the river.

According to the SWRCB, based on a firm yield study performed by CCSF, normal operations of the Hetch Hetchy system are as follows:

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[3] 38 Stat. 242.

[4] According to a memorandum by State Water Resources Control Board ("SWRCB") staff (Fuller and Stretars, SWRCB File No. 262.0 (55-07), Statement S-2635 (1982), p. 2), setting forth the findings and conclusions from their research in response to a 1982 complaint of excessive diversions, CCSF's development of the Tuolumne River for water and power upstream of the Oakdale Portal on the Foothill Tunnel consists of the following facilities:

Hetch Hetchy Reservoir	capacity 380,080 acre feet
Canyon Power Tunnel	capacity 1,100 second feet
Early Intake Reservoir	capacity 155 acre feet
Lake Eleanor Reservoir	capacity 27,100 acre feet
Lake Lloyd Reservoir	capacity 268,800 acre feet
Eleanor-Cherry Diversion Tunnel	capacity 1,140 second feet
Cherry Power Tunnel	capacity 830 second feet
Lower Cherry Aqueduct	capacity 250 second feet
Mountain Tunnel	capacity 730 second feet
Priest Reservoir	capacity 1,055 acre feet
Moccasin Reservoir	capacity 505 acre feet
Foothill Tunnel	capacity 620 acre feet

> Water from the Hetch Hetchy Aqueduct is normally released from Hetch Hetchy Reservoir through the Canyon Tunnel and Kirkwood Power House where, for quality control, it is diverted around Early Intake Diversion Dam into Mountain Tunnel. Water can also be diverted into Mountain Tunnel from the Early Intake Reservoir. From Early Intake water is conveyed to Priest Regulating Reservoir and through Moccasin Power House and then into the Foothill Tunnel and pipelines across the San Joaquin Valley.
>
> Water released from Lake Lloyd through the Cherry Power Tunnel and Holm Power House is discharged into the Cherry River at an elevation below Early Intake Diversion Dam. However, water from Lake Lloyd and Lake Eleanor can be conveyed to Early Intake Diversion Dam and into Mountain Tunnel in natural channels and diverted into the Lower Cherry Aqueduct upstream from Holm Power House.[5]

Modesto Irrigation District and Turlock Irrigation District developed reservoirs and extensive canals downstream of Hetch Hetchy, but substantially earlier in time. The La Grange Dam (capacity 500 acre feet) (1894), Modesto Reservoir (capacity 28,000 acre feet) (1911) and Turlock's Davis-Owen Lake (capacity 48,740 acre feet) (1914), together with canals and headgates for delivery to the respective Districts and a power plant at La Grange, were begun before 1910, and enlarged before 1914. The original Don Pedro Reservoir (290,200 acre feet) was completed in 1923. By agreement, the Districts divide the water diverted at La Grange with about one-third going to MID and two-thirds to TID.

CCSF and the U.S. Army Corps of Engineers joined with the Districts in the construction of "New" Don Pedro Reservoir (capacity 2,030,000 acre feet), which became operational in 1971. In exchange for CCSF's financial participation, CCSF obtained (among other things) relief from flood control responsibility on the Tuolumne River plus up to 740,000 acre feet of exchange storage rights in the reservoir.[6] The Districts are the owners of New Don Pedro and TID is the Don Pedro Project Manager. Under the exchange agreement, increased diversions to the CCSF water system are not made physically from the New Don Pedro Reservoir. Instead, CCSF's exchange storage space in the reservoir is operated to store water that is credited to CCSF, and CCSF is allowed to make additional diversions upstream to the extent that a credit exists in the reservoir, thus permitting its use by CCSF when the Raker Act would otherwise obligate it to release water for the benefit of the

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5 Fuller and Stretars, *supra*, at pp. 3-4.

6 CCSF's financial contribution obtained for it a right to 570,000 acre feet of storage in New Don Pedro called "exchange storage," and a seasonal encroachment right to up to half of the reservoir's 340,000 acre-foot reserve capacity for flood control. (*In re The Matter of Turlock Irrigation District and Modesto Irrigation District Project No. 2299* (1963) 31 F.P.C. 535, 1963 F.P.C. LEXIS 316 (LEXIS pagination used herein) ("Initial Decision").)

Districts. This exchange storage and credit system is known as the "water bank" in New Don Pedro. The Districts own and have the exclusive control and use of all water stored in Don Pedro Reservoir, including all water in the water bank. Therefore, the water bank should be more realistically viewed as being "paper water" or accounting storage as far as CCSF's "storage" rights are concerned.

The physical and legal relationship of CCSF to the Districts is that of an upstream, junior rights holder. The Raker Act, in addition to granting San Francisco authority to build on federal land, obligated CCSF to make releases to satisfy the Districts' prior rights. All releases from CCSF's facilities upstream flow into New Don Pedro. Releases from New Don Pedro are under the exclusive control of the Districts, with minimum flows set pursuant to the terms of their FERC license. No further development of the water supply system on the Tuolumne River has occurred since 1965.[7] However, in 1967, CCSF completed Canyon Power Tunnel and the Robert C. Kirkwood Powerhouse. At that time, diversion of water changed from Early Intake Dam to Hetch Hetchy Reservoir, upstream, evidently to capitalize on additional hydroelectric development capability.[8]

The capacity of CCSF's three pipelines that convey Tuolumne River water across the San Joaquin Valley to the Bay Area is 295 mgd.[9] The tunnel at Tesla Portal can carry 300 mgd. According to testimony in Examiner Hall's proceedings on the Districts' 1963 applications for a FERC license for New Don Pedro, prior to the construction of New Don Pedro, CCSF then needed an additional 674,000 acre feet of storage to yield its full claimed water right of 400 mgd. Because CCSF obtained a greater storage capacity than that in many years, it is reasonable to conclude that presently, the principle part of CCSF's infrastructure that constrains its full development of Tuolumne River rights for water supply remains in the conveyance facilities, i.e., the pipelines and tunnels carrying the water from the Sierras to the Bay Area.

II.
THE PARTIES, THE PRINCIPALS, AND THEIR RELATIONSHIP TO EACH OTHER, AND TO THE TUOLUMNE RIVER

CCSF has vested water rights to the Tuolumne River and owns real property and facilities in Hetch Hetchy Valley and in the surrounding watersheds of the Tuolumne River and Cherry River. CCSF's water department service area includes all the northern end of the San Francisco peninsula, extends south along the shores of the San Francisco Bay to include the cities of Mountain View and Sunnyvale, easterly to include the city of Milpitas, and

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7 However, in 1969 CCSF added the New Moccasin Powerhouse, a two-generator 45,000 KW capacity plant, directly adjacent to the old unit.

8 Fuller and Stretars, *supra*, at p. 17.

9 A schematic drawing showing the placement of the CCSF water supply infrastructure is attached as Exhibit A.

northerly along the eastern shores of the Bay to include the city of Hayward. More than 40 other cities, districts and agencies are supplied with water from the San Francisco system.

The Districts have vested water rights to the Tuolumne River and own real property and facilities in the foothills of that watershed and in the valley below. The Districts are two of the largest irrigation districts in the state, and have been engaged in the irrigation business since 1894 and the power business since 1924. They own and operate extensive facilities for the distribution of irrigation water and electric power in Stanislaus and Merced counties. As discussed more fully below, the Districts are intimately tied to one another and to CCSF through a long history of shared, and mostly cooperative, reliance on the Tuolumne River.

Other potential principals in the unfolding history of Hetch Hetchy and the Tuolumne River are the regulatory agencies and the courts. California's State Water Resources Control Board was asked, in complaints filed by representatives of the Sierra Club, in 1977 and 1982, to investigate whether CCSF had exceeded the scope of its appropriations. The complaints asserted that CCSF's diversions from Cherry Creek were unauthorized, and that construction of a low-head hydroelectric power plant below Moccasin Reservoir was not within the scope of the original CCSF appropriations. Although these complaints did not result in enforcement action, the SWRCB could respond to such complaints in the future, and could investigate and initiate court action to restrict unauthorized CCSF diversions if it were to substantiate the allegations.[10]

The California Department of Fish and Game ("CDFG") has statutory responsibilities for maintenance and preservation of fisheries and fish habitat. The public trust extends to fish.[11] As such, CDFG may have the authority to initiate actions to protect the fishery resource from CCSF diversions endangering fish in the upper Tuolumne River. Such actions could include engaging the SWRCB or the courts.[12]

In addition to CDFG, federal fish and wildlife agencies may have a significant role to play, particularly in evaluating and perhaps applying limitations imposed by the Federal Endangered Species Act.[13] These agencies include the Fish and Wildlife Service and NOAA Fisheries.

The Federal Energy Regulatory Commission controls licensing and a licensee's compliance with the FERC license for most large hydroelectric facilities. As part of its authority, and subject to NEPA, FERC must protect fisheries and other species reliant on the waterway's habitat. The District-owned New Don Pedro dam and hydroelectric powerplant

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10 Water Code sections 274, 1051-1052.

11 *California Trout, Inc. v. State Water Resources Control Bd.* (1989) 207 Cal.App.3d 585, 631 ("*Cal-Trout*").

12 See, e.g., *id.*, at p. 631 [relative to post-1914 water right permits].

13 16 U.S.C. § 1531 et seq.

are licensed by FERC. To the extent CCSF's diversions affect compliance with the Districts' FERC license, FERC may indirectly shape CCSF's decisionmaking with respect to the alternatives that are available to it. In addition, CCSF's water bank storage credits in New Don Pedro are subject to reduction if, in further proceedings before the FERC, the FERC increases the water release requirements for fish that impair the Districts' water entitlements.

The courts are charged with defining the validity and scope of water rights of pre-1914 appropriators when the extent of such rights or claims is in dispute. The parties themselves may initiate court action for this purpose, through a complaint for injunction, declaratory relief, or other remedy. Other water rights holders on the same stream may seek an adjudication. Citizen groups with standing to raise public trust concerns, or to assert violations of environmental protections statutes such as CEQA or NEPA, may also engage the courts and thereby affect CCSF's decisions with respect to Hetch Hetchy.

III.
THE LAW THAT APPLIES

A. Water Law

1. Pre-1914 Appropriations, Defined

Before the California Legislature adopted the Water Commission Act in 1913,[14] a right to appropriate water could have been obtained in one of two ways. Either the individual could have simply diverted water from a stream and put it to a beneficial use immediately, whereupon the person would acquire the right to use indefinitely a similar amount of water from that diversion for use on the same lands. Alternatively, after 1872, an individual might choose the "notice" method of appropriation prescribed by Civil Code sections 1410a-1422.[15] Under this second method, if the construction of the diversion works was begun within 60 days of the posting of notice, and thereafter pursued "diligently" and "uninterruptedly" to completion, the right of appropriation would relate back in time to the date the notice was posted. Eventually, important amendments were added to the notice method so that municipal appropriators would be excused from the penalty of loss of priority if their progress was interrupted by failure to develop more than the current needs of the community, provided surveys associated with future use were done within 60 days, or bonds for water facilities were authorized within six months of the date of the original notice.[16]

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[14] See Water Code section 1250 et seq. and historical annotations.

[15] Specifically, Civil Code section 1415 provides that the appropriator must post the notice at the point of diversion stating the extent of flow (measured under 4-inch pressure), the purpose and place of use, and the means and capacity of the diversion works, which notice must be recorded within 10 days in the county where the diversion is located. Change of place of use or diversion was permitted provided no injury to others occurred.

[16] Civil Code section 1416; Stats. 1911, c. 730, p. 1419, § 1.

The primary features of this code method of appropriation were notice, diligence and "relation-back." Like the non-statutory method, code appropriations depended on actually putting the water to beneficial use, after uninterrupted efforts, to perfect the right.[17] Posting a notice was not conclusive evidence of actual possession of the watercourse by which appropriative rights were acquired.[18]

A code appropriator whose notice of appropriation did not comply with the requirements of the Civil Code could not claim the benefits of relation-back.[19] However, until December 19, 1914,[20] an attempted code appropriator whose notice or recording efforts did not conform to the statute might still obtain a valid non-statutory appropriative right with a priority dating from the time it was *perfected*, by actually putting the water to a useful purpose.

The significance of this legal background becomes obvious when viewed against the factual backdrop of CCSF's and the Districts' code appropriations. The potential consequences for defective notice or recording, or for lack of diligence, are loss of priority and loss of the unexercised portion of appropriation. In a stream like the Tuolumne River, where flow is seasonal and runoff entering the waterway is at times virtually nonexistent,[21] unless one's right has a very senior status it may be ephemeral. Loss of priority may literally be fatal.

2. Validity and Scope of CCSF's Pre-1914 Appropriations

a. The Notices

The Recorder of Tuolumne County received 67 notices regarding water of the upper watershed of the Tuolumne River between 1901 and 1911 which were the genesis of CCSF's water rights. Of these, 54 were for appropriation of water, and the remainder were for rights-of-way for canals or ditches, inundation for power generation, or other water related purposes.[22] In the 1934 lawsuit filed by the Districts against CCSF, the answer filed by CCSF relied on 47 of these appropriations. In the later *Meridian* lawsuit,[23] CCSF presented evidence of 47 notices of appropriation that were owned by San Francisco at that time. A

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17 *Utt v. Frey* (1895) 106 Cal. 392, 395; *Sierra Land & Water Co. v. Cain Irrigation Co*. (1933) 219 Cal. 82, 84.

18 *Thompson v. Lee* (1857) 8 Cal. 275.

19 *Taylor v. Abbott* (1894) 103 Cal. 421, 423-424.

20 This was the effective date of the Water Commission Act, which made application to the state the sole means of acquiring an appropriative right. (Wat. Code, § 1200 et seq.)

21 See *State of California v. Federal Power Commission* (1965) 345 F.2d 917.

22 Report by Paul Bailey to Modesto Irrigation District and Turlock Irrigation District ("Bailey Report") (1934) at pp. 49-50. Bailey was formerly the California State Engineer who served as the Districts' consultant during the litigation in the early 1930's.

23 *Meridian, Ltd. v. San Francisco* (1939) 13 Cal.2d 424.

cursory review of these notices indicates they total about 817,000 miner's inches[24] on paper, far more than the amount of CCSF's actual claimed water rights today.

In his 1934 report to the Districts, prepared during litigation with CCSF that led to the first of four agreements (see Part III.D., *infra*), former California State Engineer Paul Bailey examined each of the 67 notices of appropriation in scrupulous detail.[25] Bailey believed CCSF acquired only 14 noticed appropriations which fully conform to the Civil Code requirements, yielding on their face approximately 5,780 cfs.[26] However, after analyzing the limited ability of CCSF in 1934 to store and convey the Hetch Hetchy water in a manner consistent with Raker Act and pre-1914 California law, Bailey concluded that even the validly noticed CCSF water rights would yield only approximately 200 mgd.[27]

Bailey listed several reasons for his conclusion; however, his analysis was eclipsed by the California Supreme Court opinion in *Meridian, Ltd. v. San Francisco* (1939) 13 Cal. 2d 424.

b. The *Meridian* Decision

In *Meridian*, a farming corporation with riparian rights to the Tuolumne River sued CCSF, the Districts and others, to enjoin illegal or injurious diversion, and to quiet title to its own water rights. CCSF responded by claiming it possessed valid appropriations yielding up to 400 mgd in diversions, as well as prescriptive rights to store surplus high waters in its Hetch Hetchy and Lake Eleanor reservoirs. The trial court considered the validity and scope of each of the 47 notices of appropriation on which CCSF relied, evaluated CCSF's historical and projected use of the water for power and domestic uses, and concluded that CCSF was entitled to only 142 mgd.[28]

The Supreme Court partially reversed the trial court.[29] It found that CCSF held prescriptive storage rights for surplus waters in Hetch Hetchy and Lake Eleanor reservoirs of up to 235,465 acre feet, which rights were superior to the plaintiff's riparian rights.[30] It also held that even if the notices were defective for failing to specify the storage use, a liberal construction of the notices, as compelled by *Osgood v. El Dorado Water & Deep Gravel*

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[24] The notices are expressed in miner's inches, which convert 50:1 to cubic feet per second ("cfs"). Cubic feet per second refers to a rate of flow. Thus a total of 817,000 miner's inches (plus "all water" in Eleanor Creek) equals at least 16,340 cfs, or more than 10,000 mgd - three times CCSF's current diversion.

[25] Bailey Report, *supra*, at pp. 52-157.

[26] Compare to CCSF's current claim of 400 mgd, which converts to 619 cfs, or 448,000 acre feet 365 days per year. (Initial Decision, *supra*, 31 F.P.C. at *29, n. 23.)

[27] Bailey Report, *supra*, at p. 156.

[28] *Meridian, Ltd., supra,* 13 Cal.2d at p. 442.

[29] *Id*., at p. 451.

[30] *Id*., at p. 495.

Mining Co. (1880) 56 Cal. 571, 579, necessitated a result in favor of CCSF's right to store enough water to yield the noticed 400 mgd.[31]

In sum, the *Meridian* decision solidified, but did not determine, CCSF's claim to appropriative rights yielding 400 mgd. It also gave CCSF a prescriptive right to store over 235,000 acre feet which was superior to downstream riparians as well as subsequent appropriators on the Tuolumne. Arguably the *Meridian* court's statement that CCSF's rights were sufficient to yield 400 mgd is dicta, in that the court never fully analyzed the trial court's detailed evaluation of the notices of appropriation, instead resolving the larger question by finding in favor of prescription.

c. Other References to the Scope of CCSF's Appropriative Rights

The record is muddled regarding the extent of CCSF's appropriations. In numerous later actions and fora, the 400 mgd figure has been anecdotally referenced as the extent of CCSF's appropriative water rights in the Tuolumne River. The Districts asserted 400 mgd was the legitimate scope of CCSF's water rights in their license proceedings for the New Don Pedro project before the Federal Power Commission in 1961-1963.[32] The SWRCB has concluded that something close to the 400 mgd figure represents the extent of CCSF's pre-1914 appropriations out of the Tuolumne.[33] CCSF has relied on the 400 mgd figure in protecting its own interests before the Federal Energy Regulatory Commission.[34]

However, in its testimony before the SWRCB during the interim water rights phase of the Bay-Delta hearings in July 1992, CCSF cautiously indicated it had historically relied on

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31 *Meridian, Ltd*., *supra*, 13 Cal.2d at p. 455. A problematical but unanswered question is whether CCSF's prescriptive storage right, which the court specified was superior to the plaintiff's riparian rights and code appropriations, would also be superior to the rights of the Districts. A prescriptive water right in California, being acquired outside the scheme of prior appropriation, is similar to a riparian right. Ordinarily, riparian rights are superior to appropriations. Similarly, prescriptive rights yielded title that was good not only as against the former holder, but against all the world. However, the courts viewed a prescriptive right as similar in character to the right acquired by appropriation, because both engender a trespass against the water otherwise flowing to the riparian. As a result, the concept of "first in time, first in right" was incorporated into prescriptive rights that were acquired by diversion. Since CCSF acquired the prescriptive right in 1939 with the *Meridian* decision, it appears the Districts' older appropriations are senior and, therefore, superior to CCSF's prescriptive storage rights. The so-called Fourth Agreement between the Districts and CCSF, discussed in detail below, may render this question moot.

32 In these proceedings the Districts applied for and received the right to develop a greater storage and power generator facility on the site of the old Don Pedro dam. CCSF, which paid for a substantial portion of the construction cost, was not a party to the proceeding. (Initial Decision*, supra*, 31 F.P.C. at p. 547.)

33 Although the SWRCB has no jurisdiction to bestow or revoke pre-1914 appropriations, it may nevertheless enforce the laws against unlawful diversions. (Wat. Code, §§ 1051-1052.) On occasion it has considered complaints of CCSF's excess diversion and decided not to enforce these after concluding CCSF's diversions were within their permissible scope. (See, e.g., Complaint of Robert Hackamack, Summary of SWRCB Investigation (6/15/83, and SWRCB internal memorandum of May 14, 1982, discussed *ante,* at n. 3).

34 Response to Data Request Concerning FERC Opinion 420 (June 8, 1993) at p. 41.

projected yields of "more than 300 mgd," consistent with the maximum capacity of the present Hetch Hetchy water and power conveyance infrastructure, in its long range planning.[35] In the same testimony, CCSF offered that the present annual demand of CCSF and its wholesale Bay Area customers is only 285 mgd.[36] With strict rationing, as was undertaken during the 1987-1992 drought, CCSF has successfully reduced its demand to 240 mgd.[37]

Although the consensus over time appears to be that CCSF holds pre-1914 water rights to the extent of 400 mgd, this may ultimately prove to be without foundation. CCSF has never developed the capability of diverting 400 mgd, nor has its demand even remotely approached that amount. Even the California Water Plan assumed less than 300 mgd will be consumed by the San Francisco Bay Area until the year 2020.[38]

As stated at the outset, the heart of the system of prior appropriation is diligently putting the water resource to beneficial use. "Diligence is the essence of priority" under the Civil Code.[39] There is some question about how long CCSF may continue to claim the future right to divert 30 percent more than it has been able to use in the past 100 years. Such a right is, at best, inchoate, and may well prove illusory upon closer scrutiny. The law favors reasonable *use* of water,[40] not nursing a priority which has never been exercised.

B. The Raker Act

In special session in 1913, Congress passed legislation introduced by Manteca Congressman John Raker, and sponsored by CCSF. The bill's principal purpose was to provide CCSF a right-of-way within Yosemite National Park for access to build its proposed Hetch Hetchy project, and to convey water to its power plants located outside the Park's borders, and thence to the Bay Area. As part of the conditions for the grant of right-of-way, Congress specifically recognized the Districts' prior rights to water and required CCSF to protect those rights. Further, Congress mandated that any hydroelectric power generated by CCSF pursuant to the right-of-way be used for public purpose and not for profit. Because the Raker Act allowed CCSF to build the hydroelectric facilities independent of and prior to enactment of the Federal Power Act, FERC does not have licensing authority over the Hetch Hetchy facilities.

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35 SWRCB transcript of testimony submitted by San Francisco in 1992 hearings on Interim Decision D-1630 water rights proceeding, catalogued as WRINT S-FRISCO, Exh. No. 1, p. 10.

36 *Ibid.*

37 *Ibid.*

38 California Water Plan, DWR Bulletin 160-98, assumed a maximum transfer of 330,000 acre feet, or roughly 300 mgd to CCSF from the Tuolumne River Basin. (DWR Bulletin 160-98, p. 3-40.)

39 *Sierra Land & Water Co. v. Cain Irr. Co.* (1933) 219 Cal. 82, 84.

40 *Joslin v. Marin Mun. Water Dist.* (1967) 67 Cal.2d 132; Cal. Const., art. 10, § 2.

1. The Garfield Permit

James R. Garfield was Secretary of the Interior in 1907. In 1905, CCSF had applied to the Interior Department for access right-of-way permits in Yosemite National Park to develop the Hetch Hetchy project, including Lake Eleanor. Garfield's predecessor had turned down the application based partly on President Roosevelt's belief that Congress needed to authorize such a grant.[41] Though the case appeared closed, and the intervening 1906 fire and earthquake destroyed CCSF's records, nevertheless, in 1907 the application was resurrected. Garfield granted reconsideration of CCSF's request.[42]

The Districts claimed a superior right to divert Tuolumne River water, and that CCSF's proposal could not be satisfied without injuring the Districts.[43] This claim probably amounted to an assertion of the right to divert as much water as would ultimately be needed to irrigate the Districts.[44]

Garfield compromised by granting the rights-of-way to CCSF provided the Districts' right to 1,500 cfs (Turlock) and 850 cfs (Modesto) would not be interfered with by CCSF's diversion and storage in Lake Eleanor and Hetch Hetchy Reservoir. In addition, Garfield insisted that CCSF sell its excess electrical power to the Districts, at cost.[45] Finally, the Garfield permit included a provision requiring CCSF to return to the river surplus stored water that could be used for power.[46]

With a change in Administration came a new Secretary of Interior who was not friendly to the Hetch Hetchy Project. Consequently, an order to show cause was issued by the Secretary of the Interior, R.A. Ballinger, requiring CCSF to support retaining the Hetch Hetchy reservoir in the plan of development and to establish why the Garfield Permit should not be revoked.[47] Nevertheless, it is apparent from the extensive similarity that the original Garfield Permit is the genesis of the Raker Act and, as such, is a significant resource on matters of legislative intent.

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[41] Picker, et al., *The Raker Act: Legal Implications of Damming and Undamming Hetch Hetchy Valley* (1988) 21 U.C. Davis L.Rev. at p. 1313, citing J. Clark, *Life and Adventures of John Muir* (1979) at p. 279.

[42] Picker, et al., *supra,* at p. 1314.

[43] Picker, et al., *supra,* at p. 1311, n. 24.

[44] The Districts stated: "We are entitled to the water to the amount of our original appropriations, provided we can make use of the same and in that event, we contend that there will not be water for San Francisco and its neighboring cities sufficient to meet with the least of their demands." (Picker, et al., *supra,* at pp. 1311-1312, n. 24.)

[45] The Garfield Permit, par. 6 (reprinted in Hetch Hetchy Valley, Report of Advisory Bd. of Army Engineers to Sec'ty of the Interior (1913) at p. 8).

[46] The Garfield Permit, *supra*, par. 5.

[47] Picker, et al., *supra,* at p. 1315; Report of Advisory Bd. of Army Engineers, *supra,* at p. 8.

2. The Freeman Report

CCSF responded to the order to show cause why Hetch Hetchy should not be eliminated from the permit by hiring John R. Freeman, a consulting engineer. Instead, Freeman prepared a report to the Secretary of Interior that completely redesigned the project and proposed the permit be modified. His proposal contained a series of dams, canals and tunnels that could deliver up to 400 mgd to the Bay Area as well as producing power, and which made Hetch Hetchy the indispensable hub of the system.[48] In one stroke, Freeman rendered the Garfield Permit an anachronism and put CCSF back on the offensive, with plans to divert 70 percent more water than anyone had considered possible before.

Freeman's recommendations were received by the Interior Department, which attempted to incorporate certain of his changes into the revised Garfield Permit. These failed, whereupon CCSF appealed to Congress.

3. The Legislation

The final product of this six-year effort was the Raker Act, a coalescence of the Garfield Permit and the Freeman plan. It granted to CCSF the crucial rights-of-way needed to develop a dam in Yosemite National Park on certain conditions.[49] The primary condition was that CCSF recognize the Districts' "prior rights . . . [to the extent of 2,350 cfs of the Tuolumne's natural flow.]."[50] In addition, when the amount of water released from Hetch Hetchy is lower than 2,350 cfs, CCSF must release water bringing the flow of the Tuolumne at La Grange Reservoir up to that amount if necessary for Districts' beneficial use.[51] Finally, for 60 days from April 15 each year CCSF must release up to 4,000 cfs of the Tuolumne's natural flow for the Districts to store in their reservoirs below Jawbone Creek.[52] When the natural flow is less than Districts can beneficially use, and less than 2,350 cfs, CCSF must release the entire natural flow.[53] CCSF may not export from beyond the San Joaquin Valley any more water of the Tuolumne watershed "than, together with the waters which it now has or may hereafter acquire, shall be necessary for its beneficial use for domestic and other municipal purposes."[54]

In sum, the Raker Act affects the water rights of the parties in the following ways: (a) it establishes that the Districts have rights of *at least* 2,350 cfs or (seasonal) 4,000 cfs, that are prior to CCSF's water rights; (b) it imposes a binding obligation on CCSF to protect

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48 Report of Advisory Bd. of Army Engineers, *supra,* at pp. 7-8, 19, 39.
49 38 Stat. 242.
50 38 Stat. 246, § 9(b).
51 38 Stat. 246, § 9(c).
52 *Ibid*.
53 The Act also provides for sale of water from CCSF's storage to the Districts at cost (38 Stat. 246, § 9(d)), and permits CCSF to use its power for at-cost municipal sales only. (38 Stat. 248, § 9(l).)
54 38 Stat. 247, § 9(h).

the Districts' prior rights to that extent, and (c) it requires CCSF to use its own resources before exporting Tuolumne River supplies. Nowhere does the Raker Act mention CCSF's rights to 400 mgd, nor does it grant or formalize such a right. The Raker Act specifically provides that it will not affect, in any way, the laws of the State of California regarding water rights.[55] Fundamentally, the Raker Act is only a conditional grant of right-of-way to CCSF.[56]

4. Compliance by CCSF

CCSF accepted the terms and conditions of the Act in accordance with section 9(s), within 24 days of the date the Raker Act was passed.[57] In addition CCSF filed the maps required by section 2 of the Raker Act within the three-year deadline imposed by Congress.[58] No maps were filed thereafter, nor did Congress make any provision for subsequent filings.

The rights-of-way secured by CCSF's maps filed with the Secretary of Interior included only Lake Eleanor, Hetch Hetchy and Cherry Valley Reservoirs and the lower Cherry River and Early Intake diversion sites.[59] The maps state the capacity of Lake Eleanor as 289,862.9 acre feet, Hetch Hetchy as 345,000 acre feet, and Cherry Valley as 62,408 acre feet, totaling 697,270.9 acre feet.[60] CCSF offered these maps into evidence during the *Meridian* trial. The disparity in size between Cherry Valley (Lake Lloyd) at the present time and at the time the maps presented to the *Meridian* court were drawn raises interesting questions concerning whether CCSF is already exceeding the scope of the original plan of development set forth in the Freeman Report. Nonetheless, even though the present configuration of these reservoirs is different than at the time of the legislation, the total amount of water stored in the Hetch Hetchy system does not exceed the overall capacity contemplated by the CCSF submittals to the Secretary of Interior in 1914-15.

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55 38 Stat. 250-251, § 11.

56 38 Stat. 242 and 245, §§ 8 and 9.

57 Bailey Report, *supra*, at p. 34.

58 *Ibid*.

59 Bailey Report, *supra*, at p. 35.

60 The capacity given for these same facilities today is different: Hetch Hetchy (now called O'Shaughnessy) holds 360,400 acre feet, Lake Eleanor 27,100 acre feet, and Cherry Valley Reservoir 268,800 acre feet, totaling 657,000. (WRINT - S FRISCO-1, p. 7.)

Enforcement of the Raker Act's provisions is provided for in the Act itself.[61] CCSF has previously been forced to defend in court its power sales practices alleged to be in violation of the Raker Act.[62] CCSF also lost a lawsuit by the government to enforce CCSF's road building and road maintenance obligations under the Raker Act, in Yosemite Park.[63]

"Congress may constitutionally limit the disposition of the public domain in a manner consistent with its views of public policy."[64] Just as Congress "clearly intended to require - as a condition of its grant" that San Francisco sell its power solely to municipal agencies,[65] or that CCSF honor the Districts' water rights under California law, it is reasonable to conclude that Congress also intended for CCSF to rely on Tuolumne River water only to the extent it had fully developed its other resources. Nothing in the language of the statute fixes this limitation as of a particular time; accordingly, CCSF is arguably under a continuing obligation to develop its own resources, as by recycling, conservation, desalinization, and other available means, in order to relieve the pressure of its exports from the Tuolumne River and the Hetch Hetchy Valley. The Raker Act bestows no water rights on CCSF that are independent of state law. The congressional authorization was limited, both by the conditions of the grant and by the scale of the facilities that were proposed to Congress in 1913.[66] Thus, any future expansion of CCSF's water development on the Tuolumne which intrudes on federal lands may not rely on the Raker Act authorization.

C. Federal Power Act – FERC Decision

In 1963, Francis L. Hall, the presiding examiner for the Federal Power Commission (now FERC), rendered his Initial Decision Upon the Application for License by Modesto Irrigation District and Turlock Irrigation District ("Initial Decision"). The Districts had applied for a major license to build, operate and maintain a hydroelectric facility and dam known as the New Don Pedro project, to replace their existing Don Pedro project on the

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61 "[I]n the exercise of the rights granted by this Act, the grantee shall at all times comply with the regulations herein authorized, and in the event of any material departure therefrom the Secretary of the Interior or the Secretary of Agriculture, respectively, may take such action as may be necessary in the courts or otherwise to enforce such regulations." (38 Stat. 245, § 5.)

62 See, e.g., *United States v. City and County of San Francisco* (1940) 310 U.S. 16, 26-30 [right-of-way grant is conditional on use of power for municipal purposes only; resale to private corporation found to violate the Act].

63 *United States v. City and County of San Francisco* (N.D. Cal. 1953) 112 F.Supp. 451.

64 *United States v. City and County of San Francisco, supra*, 310 U.S. at p. 30.

65 *Id.* at p. 26.

66 Congress never intended the Raker Act, which contains many limitations, to be a grant without limitation, nor did it anticipate that the diversion of water to San Francisco would ever exceed the capacity of the reservoir facilities it authorized to be constructed, that is, the capacity of those facilities after providing for the water rights of the lower appropriators . . . . Under no circumstances can San Francisco's planning for an ultimate diversion in excess of 400 [mgd] be construed as Congressional authorization therefor.

(Initial Decision, *supra*, 31 F.P.C. at **33-34.)

Tuolumne River. In describing the purposes of the project, Examiner Hall observed that the Districts were "pioneers" of irrigation through use of the La Grange Dam, completed in 1894, and through provision of low cost power to the Districts' service areas. New Don Pedro, by "making much more of the Tuolumne River water usable, will improve the base of this economy in a real and important way. It will, in short, better rearrange and retime nature to more adequately meet the water needs of those served by the Districts." However, not only the Districts were to benefit. Examiner Hall noted as well, that the project was designed to "enable San Francisco to meet its estimated water needs and to provide for flood control. In fact it clearly appears that San Francisco's desire to have the project constructed is a dominant, if not the dominant, purpose for its construction."[67] In this regard, Examiner Hall observed that San Francisco was providing about half of the financing with which the project would be constructed.[68]

In evaluating whether to grant the license and on what terms, Examiner Hall reviewed the Districts' and CCSF's water rights, and the authorizations granted to CCSF by the Raker Act. The Initial Decision stated that the license request "presents not only the question of fact as to the benefits to be derived from the construction of New Don Pedro, but also the legal question of whether what is proposed conforms with the rights, duties and responsibilities arising by virtue of the Raker Act."[69] In this regard, Examiner Hall noted that the Raker Act required CCSF to recognize the rights of the Districts to 2,350 cfs measured at La Grange diversion dam, to release the necessary amount of water to assure the flow of 2,350 cfs, and to sell additional amounts of stored water as needed for the Districts' beneficial use at actual cost, and that the Districts had the right to take free of charge 2,000 cfs of the natural flow of the Tuolumne River during the 60 day period beginning April 15th each year.[70]

The evidence placed before the Commission emphasized that CCSF urgently needed more storage space to provide for CCSF's increasing municipal water requirements, which were then becoming a matter of urgency, until the year 2015.[71] The New Don Pedro water bank, as proposed by agreement of the Districts and CCSF, would allow CCSF to store up to 740,000 acre feet in New Don Pedro, consisting of exchange credit and half of the reservoir's flood storage during the non-flood season. Examiner Hall concluded that the Raker Act requirements would be "superimposed upon any license issued by the Commission for New Don Pedro."[72] Further, Examiner Hall stated that "What San Francisco was authorized to do in the way of construction, the volume of water Congress intended it to divert, the disposition

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67 Initial Decision, *supra*, 31 F.P.C. at *3.

68 *Id.* at *12, n. 10. The federal government, through a contract between the Districts, CCSF and the U.S. Army Corps of Engineers, would provide an additional payment of over $14 million for purchase of flood control capacity in the New Don Pedro project. (*Id.* at *14.)

69 *Id.* at *6.

70 *Id.* at *5, n. 5.

71 *Ibid.*

72 *Id.* at *10.

it makes of its power, and its obligations to the Districts and others are matters governed by the provisions of the Raker Act to the extent it is applicable – not the terms of private contracts between the Districts and San Francisco. Moreover, insofar as the issuance of a license for New Don Pedro is concerned, such private contracts must yield to regulatory authority and can be given only force and effect as sanctioned by the Commission."[73] Accordingly, and as a condition of issuance of the license, CCSF and the Districts were required to enter into an agreement that was subject to the Commission's approval, requiring, among other things, that CCSF pay its fair share of the cost. Examiner Hall found that CCSF's capability for delivering water to its service area was, at that time, fixed at 210 mgd.[74] Examiner Hall explained:

> It is not the extent of the State water rights San Francisco acquired but rather the capacity of the facilities Congress authorized that is controlling. Moreover, one will search in vain for any reference in the Raker Act to an ultimate diversion of 400 mgd by San Francisco. Under no circumstances can San Francisco's planning for an ultimate diversion in excess of 400 [mgd] be construed as Congressional authorization therefor. . . . What San Francisco is here seeking is a right it does not now possess, namely, the right to divert all the water it stores in the Tuolumne River headwaters - - to the extent it is needed and possible to do so. . . . It is the ceiling imposed by the Raker Act that is wholly responsible for San Francisco's present problem which it seeks to overcome through the contribution of millions of dollars to the New Don Pedro construction cost. Stated another way, the Congressional concept embraced in the Raker Act, to which San Francisco acceded, placed the water rights of the Districts and others on San Francisco's back and this, together with the limited capacity of San Francisco's reservoirs, has led San Francisco to a dead-end. . . . [It] confronts San Francisco with the realization that it must embark upon a considerably different and better approach. But any reorientation to meet its ever-changing requirements must take into account the hard facts of the Raker Act and the Commission's regulatory power.[75]

In addition to the foregoing capacity limitations and requirements to store and bypass water for the benefit of the Districts, Examiner Hall found another limitation imposed by the Raker Act precluded CCSF from utilizing power produced by the Tuolumne River development in Yosemite Park for sale to private entities for resale. Examiner Hall found that a similar ceiling operated by virtue of the Raker Act on the ultimate development of CCSF's hydroelectric capacity. Examiner Hall questioned whether CCSF had the authority under the Raker Act to develop its Canyon power plant and other new facilities that tripled the output of the development from what was the system's capacity as proposed at the time

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73 *Id*. at **15-16.
74 *Id*. at *32.
75 *Id*. at **34-35.

the Raker Act was passed, but because CCSF was not technically a party to the licensing proceedings, did not go so far as to demand additional evidence or render a ruling in this regard.[76]

Examiner Hall's position throughout the Initial Decision was that the Raker Act was consistent with, and even the "mould" in which the later Federal Power Act was cast, and that therefore, any interpretation of the Commission's authority and responsibility should properly be guided by the Raker Act's provisions.[77] Accordingly, the fact that CCSF could under California law claim a municipal preference vis a vis irrigation purposes was irrelevant. Because the Raker Act specified that the Districts' water rights were subject to protection under the Raker Act, the Commission must afford that same protection. In effect, the Raker Act "modified the State water permits San Francisco had obtained," according to Examiner Hall, and as a result, CCSF could not interfere with the Districts' rights.[78] Examiner Hall avoided the potential conflict by distinguishing between water rights the Districts and CCSF had already perfected and used from water rights proposed to be used for irrigation and municipal purposes. Increases in storage by the Districts, or over the 210 mgd capacity of CCSF's then maximum diversions, were subject to limitation by the Federal Power Commission.[79]

The decision to grant a license also required the Commission to implement the Federal Power Act's provisions for protecting fisheries affected by the proposal. Examiner Hall was reluctant to force the Districts alone to bear the entire burden of fish releases from New Don Pedro. Thus, although maintenance of minimum stream flows in the Tuolumne River was required at the La Grange Bridge, Examiner Hall required CCSF and the Districts to enter into an agreement that would apportion the burden between them, both in water and economic costs, subject to the Commission's approval, and subject to reopening in the future.[80]

Finally, Examiner Hall determined that California's needs for recreational facilities were "far greater" than in 1913, and that the Districts and CCSF should therefore be required to construct and maintain such facilities as a condition of the license. The Raker Act was explicit, and legislative history supports congressional intent to insure that recreational opportunities would remain available and accessible in the Park, which would be displaced

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[76] *Id*. at **5, 36-37, 47. Examiner Hall did go so far as to suggest that further investigation might be warranted whether San Francisco's development and recent construction of additional facilities was in conformity with the Raker Act authorization. (*Id*. at *47.)

[77] *Id*. at *53.

[78] *Id*. at *56.

[79] *Id*. at *62. For this, Examiner Hall relied on the authority contained in Section 10(a) of the Federal Power Act, authorizing the Commission to approve plans for hydroelectric projects in a waterway for improvement of fish and wildlife enhancement and other beneficial public uses and to modify such proposals before approving them. (*Id*. at **60-61.)

[80] *Id*. at **79-80.

by Hetch Hetchy reservoir.[81] Accordingly, Examiner Hall required the Districts to develop a master plan, subject to the Commission's approval, for recreational use of the New Don Pedro reservoir and to acquire additional lands for recreation, fish and wildlife purposes, and that CCSF should share in paying for these facilities.[82]

The examiner's Initial Decision was submitted to the Commission. The Districts, the State of California, the Secretary of the Interior and the Commission staff filed exceptions.[83] The license was issued and further disputes were carried forward into the courts. By the time the Ninth Circuit Court of Appeals reviewed the matter, in 1965, the issues had been winnowed down to whether the license requirement for maintaining certain minimum stream flows in the Tuolumne River at La Grange Bridge for fish run purposes was a proper condition.[84] The Court held that it was. In so holding, the Court of Appeals rejected the Districts' argument that nothing in the Federal Power Act should be construed to modify or repeal any Raker Act provisions, and that the fish flow requirement would impermissibly impair their irrigation water rights protected by the Raker Act. The Court said that the Districts could continue to receive their Raker Act flows "as long as they are content with their present facilities. That act did not give them the right to use the public lands they now wish to utilize in connection with the New Don Pedro project. With regard to those public lands, the districts are in the same position as any other applicant for a license -- if they are to use those lands they must accept the reasonable restrictions and obligations attached thereto."[85] At the time the Commission must reevaluate the fish releases, the Court held that the Commission could impose "burdens upon the districts warranted by the benefits derived by San Francisco on the assumption that the latter will reimburse the districts for any such expenditures."[86] Consistent with the examiner's Initial Decision, the Court required CCSF and the Districts to enter into an agreement making clear their respective rights and obligations and further, that the Districts would be entitled to reimbursement from CCSF for the burden of any fish releases the Commission would require in the future.[87]

D. Contract Law - The Four Agreements

In the period following passage of the Raker Act, the Districts and CCSF found it generally possible to "live together in a common sense way."[88] By coordinating their activities, the parties were able to "maximize the quantity of water each [was] able to appropriate."[89]

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81 *Id.* at **88-89.
82 *Id.* at *113.
83 *State of California v. Federal Power Commission* (1965) 345 F.2d 917, 921.
84 *Ibid.*
85 *State of California v. Federal Power Commission, supra*, 345 F.2d at p. 924.
86 *Id.* at p. 930.
87 *Id.* at p. 929.
88 Initial Decision, *supra*, 31 F.P.C. at p. 548.
89 *Ibid.*

1. First Agreement

Nevertheless, in 1933 the Districts became so concerned with the possibility that CCSF's water exports from the Tuolumne River watershed would harm their interests that they filed suit to quiet title to the waters of the Tuolumne River in themselves, and to enjoin the construction of CCSF's "tunnels, pipe-lines and conduits and from carrying away the waters of the Tuolumne."[90] CCSF answered the Districts' Complaint. Following more than six years of negotiations, a settlement was reached when the parties, in February 1940, entered into the "First Cooperative Agreement Between T.I.D., M.I.D. and City and County of San Francisco." The First Agreement, a remarkably simple document, is mainly a truce, or an agreement to agree. Importantly, it also recognizes CCSF's expectations of eventually needing 400 mgd.[91] Additionally, the agreement "recommends" proper conservation of the Tuolumne waters, continued cooperation, and recognition of the Raker Act's applicability.

2. Second Agreement

The Second Agreement (November 1943) referred to the First Agreement, and adopted its twin goals of conservation and cooperation. It set forth the parties' plan to continue developing the Tuolumne River, specifically by building the "Cherry River Project" and the New Don Pedro Project. Additionally, in the final paragraph, the parties agreed to operate "any additional storage"[92] to meet the requirements of domestic water supply, irrigation, power and flood control, "and according to the agreement" of 1940.

3. Third Agreement

With the signing of the Third Agreement six years later, the 400 mgd demand figure was adopted outright. The express purpose of this agreement was "to provide for the storage, management and control of the waters of the Tuolumne River Watershed in such a manner as to assure that water will be available in sufficient quantity to meet the estimated ultimate irrigation requirements of one million one hundred thousand acre feet annually for use by the Districts and the estimated ultimate requirements of City for the diversion of four hundred million gallons daily to the Bay Area . . . ."[93]

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90 Complaint, Bailey Report, *supra*, Appendix A.

91 Paragraph Four of the First Agreement states, in part: "Extensive hydrographic studies . . . indicate that there is sufficient water available from the Tuolumne River watershed *when properly conserved* to meet the ultimate irrigation demands of the Districts as well as the City's estimated demand of 400 million gallons daily for domestic purposes." (Emphasis added.)

92 See Second Agreement, paragraph 4. "Additional storage" probably was limited to the expressly contemplated Cherry Valley Reservoir and New Don Pedro Project.

93 Third Agreement, art. 2.

The Third Agreement adopts the Second Agreement's choice of means for assuring the respective anticipated demands of the Districts and CCSF, that is, to build New Don Pedro and Cherry Valley Dams.[94] The Third Agreement gave to CCSF "the right to intercept, divert and use District Raker Act water in an amount equal to and in exchange for the water actually in storage in New Don Pedro Reservoir for the City's credit."[95] In addition, flood control storage space not required for actual flood control was allocated to the Districts and CCSF on a 50-50 basis.[96] CCSF would pay the primary costs of building New Don Pedro as consideration for the additional exchange storage space it acquired, but the project was to be owned, maintained and operated by the Districts at their expense.[97] The Third Agreement was executed June 30, 1949.

4. Fourth Agreement

Fifteen years later, after lengthy and complex licensing proceedings for the New Don Pedro Dam, and ten years after completion of Cherry Valley/Lake Lloyd, the parties entered into the Fourth Agreement. The Fourth Agreement was required by the Federal Power Commission as a condition of the license for New Don Pedro, a requirement that was confirmed by the Ninth Circuit Court of Appeals.[98] This last agreement expresses that it was intended to "set forth the respective responsibilities of the Districts and the City in the New Don Pedro Project . . . ."[99] It specifically was not "intended to affect, alter, or impair in any manner" the rights of the parties to the Tuolumne River "acquired or existing" under California law.[100] Additionally, the parties agreed to "recognize and abide by" the Raker Act's provisions.[101]

A main purpose of the Fourth Agreement was to allocate the burden of license requirements affecting operation of New Don Pedro in such a way that the Districts' water rights would continue to be protected, as well as assuring that CCSF would receive the benefit of additional storage space in the reservoir.[102] To this end, a "Water Bank Account" was

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94 *Id*. arts. 3-9.
95 *Id*. art. 14.
96 *Id*. art. 13.
97 *Id*. art. 17.
98 *State of California v. Federal Power Commission, supra*, 345 F.2d at p. 929.
99 Fourth Agreement, par. 11.
100 *Id*. art. 2.
101 *Ibid*.
102 *Id*. arts. 5-9.

established.[103] In addition, a formula was created for sharing the responsibilities for water release license conditions for fish purposes below Don Pedro. Those responsibilities may be changed, pursuant to further proceedings before the FERC, where the releases adversely affect the Districts' water entitlements.[104] In such case, the storage credits in New Don Pedro would be recomputed to apportion the burden of the water releases 51.7121 percent to CCSF, and 48.2879 percent to the Districts.[105]

Legally, the Fourth Agreement can be understood as a contractual overlay that enhances full use and enjoyment of their water rights. Developed by CCSF and the Districts to maximize the yield of their respective right to Tuolumne River water, the Fourth Agreement, through the Water Bank mechanism, provides an agreed method for rescheduling releases to and from storage that disregards their relative legal priorities (at times and under agreed specific circumstances). This contractual overlay is not by any means an abandonment of the priority system that is imposed by state law and recognized by the Raker Act and the license for New Don Pedro. Rather, it is a cooperative solution developed in response to the challenges imposed by these laws in combination with such additional constraints as severe fluctuations in Tuolumne River flow and the high cost of new infrastructure.

The New Don Pedro FERC license required reexamination of the minimum fish flow releases after the first twenty years of project operation. Under a 1995 FERC-mediated settlement agreement ("1995 Settlement Agreement") among the Districts, CCSF, Federal and State fish agencies, and environmental groups, the Districts agreed to provide higher minimum fish flows below New Don Pedro. The settlement agreement was made possible because the Districts and CCSF entered into a separate settlement agreement to share the

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[103] The Water Bank Account functions as follows:

> CCSF contributed capital to the construction of New Don Pedro for the right to pre-release and subsequently hold back up to 570,000 AF of the District's entitlement between elevations 6000.0' and 801.9' In addition they could store water in the Flood Control Space up to one-half of the 340,000 AF.
>
> CCSF receives a credit to their water bank account when the inflow into Don Pedro exceeds the District entitlement. Since the inflow to Don Pedro is dominated by releases from the Hetch Hetchy Project, CCSF can obtain a credit by releasing a volume of water greater than the natural flow or the entitlement amounts, whichever is less . . . .
>
> CCSF receives a debt to their water bank account when the inflow into Don Pedro is less than the District's entitlement. This occurs when CCSF releases less than the natural flow or the District's entitlement whichever is less.
>
> A maximum of 570,000 AF can be credited by the CCSF in Don Pedro when the reservoir storage is below 1,690,000 AF (elevation 801.9') . . . .
>
> When the reservoir storage is greater than 1,690,000 AF then CCSF can credit their account an additional amount up to one half the difference between the total storage and 1,690,000 . . . . Any credits beyond this total would not be added to the CCSF account . . . .

(TID, Summary of Don Pedro Water Bank Accounting, October 16, 1987.)

[104] *Id.* art. 8.

[105] *Id.* art. 8(b).

burdens of increased fishery releases from New Don Pedro. This agreement was a further outgrowth of the continued process over the years wherein the Districts and CCSF struggled for control of the resource and ultimately agreed to resolve their differences by agreement. A second Districts-CCSF settlement agreement was entered into to cover the funding of various measures specified in the 1995 Settlement Agreement. These costs were split 51.7121 percent for CCSF, and 48.2879 percent for the Districts, consistent with article 10(c)(2) of the Fourth Agreement.[106]

The First through Fourth Agreements have been a fairly successful attempt to work out means of coexisting and sharing the Tuolumne River. However, predictably, the Districts and CCSF do not always agree on what the agreements say or mean. In California law, the interpretation of contracts is to give effect to the intent of the parties. Discerning this intent requires a ready knowledge of the history of their development of the resource, some of which is set forth above. It is an open question whether there is sufficient flexibility in the agreements to accommodate unanticipated changes such as the future population growth that is projected for both CCSF's and the Districts' service areas in northern California, or consideration of the restoration of Hetch Hetchy Valley. However, the history of their relationship does provide evidence that CCSF and the Districts can work together, as they have in the past, to address changing demands and competing interests.

E. Public Trust Doctrine and the Constitutional Requirement of Reasonable Use

1. Public Trust Doctrine

The public trust doctrine provides that certain natural resources are held in trust by the state for the benefit of the public. Originally a concept from Roman law, the public trust doctrine evolved in English common law to confer upon the sovereign ownership of "all of its navigable waterways and the lands lying beneath them 'as trustee of a public trust for the benefit of the people.'"[107] Upon its admission to the United States, California obtained title to its navigable waters and underlying lands to be held in trust.[108]

The public trust doctrine has been traditionally applied to protect public uses related to navigation, commerce and fisheries.[109] In two seminal cases, the California Supreme Court extended the public trust purposes to include environmental preservation and aesthetics.[110] Although English common law and early American cases assumed that the public trust extended

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106 Agreement on Allocation of Certain FERC Costs Between CCSF and [Districts]; TID Resolution No. 96-12, MID Resolution No. 96-13.

107 *Colberg, Inc. v. State of California ex rel. Dept. Pub. Wks.* (1967) 67 Cal.2d 408, 416, citations omitted.

108 *National Audubon Society v. Superior* Court ("*National Audubon*") (1983) 33 Cal.3d 419, 434, citing *City of Berkeley v. Superior Court* (1980) 26 Cal.3d 515, 521.

109 *Marks v. Whitney* (1971) 6 Cal.3d 251, 259.

110 *Marks v. Whitney, supra,* 6 Cal.3d at pp. 259-260; *National Audubon, supra,* 33 Cal.3d at p. 437.

only to tidal lands, California courts have extended the scope of the public trust resource to all navigable waters and even to nonnavigable waters that affect navigable waters.[111] The California Supreme Court also held that water rights are subject to the public trust doctrine.[112] Moreover, the public trust doctrine implies a duty of continuing supervision and the state is empowered to re-analyze water right allocations.[113]

In the past, California courts have applied the public trust doctrine in ways that significantly affected California's economy and property rights. For instance, it was a public trust doctrine decision of the California Supreme Court in 1884 that ended the California gold rush – a phenomenon that had driven California's economy for the prior forty years.[114] In *Gold Run*, hydraulic miners were diverting the waters of the American River to create high-powered water cannons used to wash away entire hillsides for gold mining purposes. The tailings from these operations went into the American River and were causing several problems, including increased flooding due to the raised riverbed; impairment of navigation, and impacts to water quality to the extent that American River water was no longer fit for domestic consumption.[115] The *Gold Run* court found that these mining operations impaired the public trust values of the American River and, on that basis, banned hydraulic mining. The court's ruling effectively prohibited large-scale gold mining in California. The result of this ruling was the cessation of the Gold Rush and the beginning of California's transformation from a mining economy to an agricultural economy.

One century later, the California Supreme Court again invoked the public trust doctrine in the context of water rights for diversions from non-navigable tributaries to Mono Lake.[116] In *National Audubon*, the court held that water rights were subject to ongoing review under the public trust doctrine. The *National Audubon* decision did not determine whether the Los Angeles Department of Water and Power's ("LADWP") diversions should be reduced. Instead, subsequent proceedings before the State Water Resources Control Board resulted in amendments to LADWP's licenses that significantly reduced the amount of water that may be lawfully diverted from the streams tributary to Mono Lake.

There is no doubt, therefore, that the public trust doctrine must be considered in adopting the Capital Improvement Program ("CIP") and, independent of the CIP, in evaluating the continued use of the Hetch Hetchy Valley as a water impoundment for the benefit of San Francisco.[117] The public trust does not trump other water uses, however, and the State may

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[111] *Marks v. Whitney*; *National Audubon*.
[112] *National Audubon, supra,* 33 Cal.3d at p. 426.
[113] *Id*. at p. 447.
[114] See *People v. Gold Run Ditch & Mining Co.* ("*Gold Run*") (1884) 66 Cal. 138.
[115] *Gold Run*, *supra,* 66 Cal. at p. 152.
[116] *National Audubon, supra,* 33 Cal.3d at pp. 446-447.
[117] Significantly, the land beneath Hetch Hetchy Reservoir is patented land that is owned in fee by CCSF. (Garfield Permit, ¶ 1.)

dispose of public trust resources when it serves the public good.[118] Whether the Raker Act validly disposed of the public trust resources of the Hetch Hetchy Valley is an open question.[119] Separate and apart from the Raker Act provisions, San Francisco's appropriative water rights must also be analyzed through the lens of the public trust doctrine. This analysis should be independent of the analysis of whether the Raker Act contains evidence of the federal government's intent to dispose of the public trust resources within the Hetch Hetchy Valley.

As described above, application of the public trust doctrine to California water rights or other resources involves a balancing of interests and uses.[120] San Francisco and others have long held interests in the waters stored in the Hetch Hetchy Valley and the hydroelectric power generated therefrom. It seems unlikely that any court would interpret the public trust doctrine to require removal of O'Shaughnessy Dam and restoration of the valley if doing so resulted in the unmitigated loss of stored water and power generation for San Francisco. Instead, the balance of interests swings in favor of restoring the Hetch Hetchy Valley only when San Francisco and other interested water and/or power users can be made whole or mostly whole in the process.

2. Article X, Section 2

Article X, Section 2 is an amendment to California's Constitution that applies a reasonableness standard to all California water use, regardless of the nature of the water right. The California Legislature amended the Constitution in 1928 in response to a Supreme Court decision holding that a riparian diverter owed no duty of reasonableness in water use to an upstream appropriator. Subsequent caselaw interpreting Article X, section 2 established that the reasonableness of the water use is evaluated based not only on local competing uses, but also on statewide water conditions.[121] Moreover, reasonableness of a particular use may change over time – what was once a reasonable use of water may become unreasonable at a later date.[122]

The reasonableness requirement of Article X, section 2 applies to the CIP and San Francisco's continued diversion and storage of Tuolumne River water at Hetch Hetchy. In general, diversion and storage of water is not an unreasonable use. Article X, section 2 compels an analysis, however, of the reasonableness of the particular diversion and storage.[123] A party

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118 *Eldridge v. Cowell* (1854) 4 Cal. 80.

119 See *People v. California Fish Co.* ("*California Fish*") (1913) 166 Cal. 576, 597 [where California Supreme Court held that statutes purporting to dispose of a trust resource will be "carefully scanned" for the requisite intent, either clearly expressed or necessarily implied]. Of note, the *California Fish* holding applies to state statutes, not federal statutes like the Raker Act. Nevertheless, federal law also recognizes the public trust doctrine and *California Fish* is likely to be persuasive authority regarding the intent expressed in the Raker Act.

120 See *City of Berkeley v. Superior Court* (1980) 26 Cal.3d 515, 534.

121 See *Tulare Irrigation District v. Lindsey-Strathmore Irrigation District* ("*Tulare Irrigation*") (1935) 3 Cal.2d 489, 524-525; *Joslin v. Marin Municipal Water District* (1967) 67 Cal.2d 132, 140.

122 *Tulare Irrigation, supra,* 3 Cal.2d at p. 567.

123 See *Tulare Irrigation, supra,* 3 Cal.2d at pp. 524-525.

deemed to be diverting, using or storing water in an unreasonable manner can be required to alter its practices and face "some inconvenience or to incur reasonable expenses."[124]

Significant issues surround the reasonableness of continued use of the Hetch Hetchy Valley for water impoundment. Whether San Francisco even needs Hetch Hetchy is probably the most pressing issue. Expanded use of New Don Pedro Reservoir in cooperation with the Turlock Irrigation District and Modesto Irrigation District is a concept that must be analyzed in determining whether San Francisco's continued flooding of Hetch Hetchy Valley remains reasonable, particularly in light of the potential to divert Tuolumne River water downstream, at or near the Delta. Significant issues are also raised by the hydroelectric power generation that may be forfeited if O'Shaughnessy is removed and the valley drained. The impacts to the environment, downstream water users, and the restored Hetch Hetchy Valley also must be considered. Finally, the dollar cost to San Francisco of removing O'Shaughnessy and restoring the valley must be weighed.

IV.
LIMITATIONS ON CCSF'S EXERCISE OF WATER RIGHTS

A. The Physical Limitations – Demand and Supply

1. Demand

Historically, beginning with the Freeman Report, CCSF has clung to its reliance on the Tuolumne River appropriations to meet its projected demand for the larger Bay Area population. CCSF has rarely wavered in its projected demands. This CCSF position, anchored in the Freeman Report's assumption, is maintained by CCSF despite the fact that the East Bay Municipal Utility District, considered within the Freeman Report as part of CCSF's service demand, has developed a separate Mokelumne River supply to meet its demand, and even though the state and federal governments have developed additional storage sites as potential alternatives to the Tuolomne River resource.

A demand of 400 mgd converts to 448 thousand acre feet ("TAF") per year. Combined with the Districts' ultimate demand of 1.1 million acre feet ("MAF"), the Tuolumne must produce 1.5 MAF just to supply these three water users. As the *Meridian* lawsuit attests, there are others reliant on the Tuolumne watershed as well, not including fishery and water quality requirements.[125]

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124 *People ex rel. State Water Resources Control Board v. Forni* (1976) 54 Cal.App.3d 743, 751-752.

125 The SWRCB's computer printouts show some 111 additional water right holders, claiming the right to divert another 478 TAF for the Tuolumne River.

2. Supply

The total present developed supply, gleaned from CCSF and the Districts' combined efforts, yields roughly 1.3 MAF a year for storage and diversion. CCSF estimates that the Hetch Hetchy project yields about 240 mgd or 268.8 TAF annually.[126] The Districts' estimates indicate that CCSF produces between 302 and 317 TAF.[127]

The Districts divert roughly 1 million acre feet per year. In dry years, the Districts have had to rely on carryover storage in Don Pedro, including the water bank water, as well as draw from the groundwater resources. When fishery releases are subtracted, the Districts' supply is severely constrained.[128] The highest storage yield at Don Pedro in one year was 1.3 MAF in 1978, but this was uniquely the result of two critically dry years (1976-1977) followed by a record wet year (1978).

There is not enough developed supply to meet the projected demands of CCSF and the Districts, not to mention others who are reliant on the watershed. If the parties, particularly CCSF, continue to press for their maximum "entitlement," it is apparent that injury to these water rights holders, including riparians, will result, and that litigation will follow. In view of the legal uncertainty of application of principles such as prescription on existing priorities, diligence, and the public trust doctrine, as well as expanding environmental protections, neither CCSF nor the Districts can rest assured that the Tuolumne River will be able to meet their needs in full indefinitely.

B. CCSF's Diligence Requirement

Perfection of an appropriative water right requires that water be actually put to reasonable beneficial use with the exercise of due diligence. While CCSF may claim a right of up to 400 mgd, it may not have maintained that right if it does not have the current capacity to divert this quantity or if it has not, in fact, done so in the past. This argument, if pursued, would become more potent over time. In essence, it is that CCSF cannot expand its current exports, or perhaps even continue its current diversions from Hetch Hetchy, because it failed diligently to bring to completion facilities needed to fully protect the right. There are statutory and judicial exemptions from the diligence requirement. Cities could postpone development of water and power that was not immediately needed.[129] Also, an appropriator

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126 SWRCB D-1630 Transcript, WRINT, S FRISCO, Exh. No. 1.

127 See R. W. Beck's April 1992 analysis, "Don Pedro Project - Reservoir Operations report - FERC Article 39, Project 2299" at pp. 4-9, 10.

128 The settlement agreement between the Districts and CDFG assigns 15-16 percent of the current year's inflow to the Tuolumne River's minimum instream flows. (Testimony of Ernest Geddes before SWRCB, Interim Water Rights Phase of Bay-Delta Hearings, D-1630 Transcript, WRINT-TID/MID 2, at p. 9; 1992 Settlement Agreement, App. A, at pp. 12-17.)

129 Civil Code section 1416.

who steadily pursued a long-term plan of development could be protected from the requirement to immediately put the full claimed quantity of water to beneficial use.[130]

The courts today are inclined to take a less tolerant view of cities that fail diligently to put their appropriations to beneficial use. In *Cal-Trout, supra*, 207 Cal.App.3d 585, the Third District Court of Appeal had to decide whether the City of Los Angeles, through its Department of Water & Power, could expand its water exports from Inyo and Mono counties by "extensions" of its permits to appropriate water obtained in 1953. Although the *Cal-Trout* opinion is factually distinguishable because it does not involve pre-1914 rights, the policy on which the decision is grounded is just as applicable to the case against CCSF's expansion.

Los Angeles sought to excuse its failure promptly to develop and use its full appropriation, and thereby escape the liability for releasing fishery flows that would accompany a later-acquired permit, by arguing that it could not have diverted more when the appropriation was initiated.[131] The court rejected Los Angeles' argument, saying "[t]he logical extension of L.A. Water and Power's legal theory would permit an appropriator of water from a complex of sources to lock up artificially high 'vested' water rights from each of the sources by manipulating the sources from which it elected to draw its water levels despite the inability to apply such waters to beneficial use. *Such cold storage is not permitted by law.*"[132] The court went on to observe that if Los Angeles had simply constructed its first phase of the diversion under a permit issued in the 1950's, and then returned to the SWRCB for a new permit in the 1980's to construct the next phase, there would have been "no plausible claim of retroactivity" to support its argument in favor of its vested right for an increased diversion. The court stated that Los Angeles' conduct had allowed the original permit process "to tarry interminably and then [be] improperly employed to authorize a new project, which required a new permit, under the guise of 'extending' the original project."[133] Finally, the court noted that the "extensions" were unjustified under the pertinent statutes "calling for diligence in the completion of water projects."[134] Thus, the expansion would undermine the priority system and contravene diligence requirements.

The similarities between *Cal-Trout* and CCSF's potential expansion of its diversions from the Tuolumne River are striking. CCSF's apparent inability to divert more than 300 mgd is unrelated to the variant flow of the Tuolumne River. Instead, it is purely the result of CCSF's failure initially to develop more capacity for transporting water across the San Joaquin Valley. CCSF, like Los Angeles, is a municipality, yet the court found Los Angeles was not excused from the statutory diligence requirements. While CCSF's appropriations are

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130 *Haight v. Costanich* (1920) 184 Cal. 426, 432.
131 *Cal-Trout, supra,* 207 Cal.App.3d at p. 618.
132 *Ibid.*, emphasis added.
133 *Ibid.*
134 *Ibid.*

pre-1914 appropriations and Los Angeles derived its right from a state-issued permit, this distinction could well not make any difference. Both appropriations are required to be completed with diligence, and the pertinent municipal exemptions from diligence are substantially similar.

Additional support for holding CCSF to its current level of diversions on the basis of failure to diligently develop the Hetch Hetchy project to completion can be found in the Raker Act. This requirement, imposed by Congress, is independent of and in addition to California law. The Raker Act imposes a forfeiture provision that would apply if CCSF lapsed in constructing the project for more than three years, unless the lapse were due to reasons beyond CCSF's control.[135]

In summary, it appears that the diligence requirement could interfere with CCSF's attempt to expand diversions from the upper Tuolumne River beyond the current rate of 300 mgd. It is uncertain whether the bar would extend to existing diversions from Hetch Hetchy that have been undertaken by CCSF over the years, with delays in development that exceeded the three years allowed by the Raker Act. This consideration is, of course, further complicated by various water quality requirements imposed over time, including those associated with South Delta salinity, dissolved oxygen, TMDLs, salt, boron and others.

C. <u>Change Point of Diversion</u>

California's system of prior appropriations dictates that the oldest right on the river (along with riparians) has the right to the first portion of the available water, with what remains being available to the junior appropriators in order of their notice or permit. Both CCSF and the Districts rely on pre-1914 appropriations for their water rights. The Districts' Tuolumne River rights are senior to CCSF's. The priority system allows the Districts to divert their entire appropriation before San Francisco may take even one drop of water from its appropriation.

The Raker Act also requires CCSF to operate its Hetch Hetchy system in a manner that recognizes the Districts' prior rights. Section 9 of the Raker Act imposes a duty on San Francisco to protect the Districts' "prior rights . . . [to the extent of 2,350 cfs of the Tuolumne's natural flow] . . . as now constituted under the laws of the State of California, or as . . . may be hereafter enlarged."[136] CCSF must also release an additional quantity of water from April 15 through June 15 annually (up to 4,000 cfs of the Tuolumne's natural flow) for the Districts to store in their reservoirs below Jawbone Creek.[137]

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135 38 Stat. 244-245, § 5.
136 38 Stat. 246, § 9(b).
137 38 Stat. 246, § 9(c).

Presently, San Francisco obtains nearly 300 mgd from the upper Tuolumne River. An expansion of this to 400 mgd presumably would injure the Districts (or perhaps others) in many years. Application of the priority rules may restrict CCSF's diversions from the upper Tuolumne to their present diversion rate of about 300 mgd. If the Districts suffered injury by CCSF's *existing* diversions, as in periods of drought, either the Raker Act or California's priority system could restrict CCSF diversions. Such constraints might be avoided if CCSF were to change its point of diversion to a location downstream of the Districts and other senior water rights holders. Likewise, if CCSF constructed an intertie to divert water from New Don Pedro to the conveyance facilities that run beneath the reservoir, this change in place of diversion could add flexibility to operations that would avoid similar constraints. Such a facility would, of course, need to be approved by the Districts, who are the sole owners of the New Don Pedro facilities and of all water stored therein. This approach avoids injuring others while still allowing CCSF to obtain its full claimed entitlement.

Changing the point of diversion has always been permitted in the appropriation system. The earliest authority is *Kidd v. Laird* (1860) 15 Cal. 161. *Kidd* held that a change in "mode and objects of use" is justifiable, so long as alterations "shall not be injurious to those whose interests are involved."[138] Civil Code section 1412 (now Water Code section 1706) codifies the rule announced in *Kidd*. Later judicial refinements have clarified that either a change in point of diversion or means of diversion is allowed for pre-1914 appropriations, provided that no injury is dealt to others with vested water rights.[139] Thus, CCSF is plainly entitled to alter its point of diversion for any portion of its pre-1914 entitlement to 400 mgd, or all of it, so long as there is no injury to senior water rights holders, including the Districts.

D. The Raker Act Conditions Development of Available Supplies

The Raker Act requires San Francisco to first develop and use its own resources before exporting Tuolumne River supplies. It states that CCSF may not export from beyond the San Joaquin Valley any more water of the Tuolumne watershed "than, together with the waters which it now has or may hereafter acquire, shall be necessary for its beneficial use for domestic and other municipal purposes."[140] This Raker Act condition may effectively bar expansion of CCSF's exports, and may require CCSF to curtail its current diversions until it can demonstrate that it has developed such local resources. As stated previously, nothing in the Raker Act indicates that the duty to develop such available resources was fixed to end at a definite time.

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[138] *Id.* at pp. 180-181.

[139] *Byers v. Colonial Irrigation Co.* (1901) 134 Cal. 553, 554-555; *Craig v. Crafton Water Co.* (1903) 141 Cal. 178, 183; *Hand v. Cleese* (1927) 202 Cal. 36, 45.

[140] 38 Stat. 247, § 9(h).

In the past, it had been argued that alternative sources, such as the State Water Project or the Central Valley Project, were infeasible for CCSF to rely on due to the constraints of capacity in various elements of the systems, including the South Bay Aqueduct. This may not hold true today. Today, feasibility analysis must take into account the environmental impacts that require mitigation in designing an expansion or otherwise modifying or updating the conveyance system for exporting Hetch Hetchy supplies. These environmental considerations may weight the feasibility analysis against expansion, modification or updating, and in favor of other alternatives. Furthermore, recycling, desalinization and wastewater recovery are increasingly available today, are independent of the Tuolumne River supply altogether and, therefore, must also be evaluated as elements to the expansion, modification or updating of CCSF Hetch Hetchy facilities. Thus, alternatives may exist that were perceived to be unavailable previously.

The Raker Act authorizes enforcement of its provisions by federal agencies. It provides: "[I]n the exercise of the rights granted by this Act, the grantee [CCSF] shall at all times comply with the regulations herein authorized, and in the event of any material departure therefrom the Secretary of the Interior or the Secretary of Agriculture, respectively, may take such action as may be necessary in the courts or otherwise to enforce such regulations."[141] Thus, unless CCSF were able to demonstrate that it had fully developed local resources, it could be prevented from diverting existing or expanded water supplies from Hetch Hetchy by the agencies having such enforcement power under the Raker Act.

CCSF has had to defend its actions against Raker Act violations in the past.[142] CCSF also received a clear warning in the Federal Power Commission Examiner's Initial Decision, 31 F.P.C. at page 547, where Examiner Hall observed, "Congress never intended the Raker Act . . . to be a grant without limitation."[143]

E. <u>Storage in Don Pedro</u>

CCSF's right to exchange storage in Don Pedro Reservoir derives from contract. (See Fourth Agreement Between the City and County of San Francisco and the Turlock Irrigation District and the Modesto Irrigation District, dated 1966 ("Fourth Agreement.") In some respects the provisions of this Fourth Agreement have been incorporated into relevant District water rights before the SWRCB and FERC. Obligations with respect to some of its provisions have been modified pursuant to subsequent agreements and regulatory agency actions.

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141 38 Stat. 244-245, § 5.

142 See *United States v. City and County of San Francisco, supra,* 310 U.S. 16 [the right of way grant was conditional use of power for municipal purposes].

143 Initial Decision at p. 547.

Under Article 7 of the Fourth Agreement, CCSF releases water from its upstream facilities at times when, pursuant to its water rights, it is not obligated to make releases. An accounting record is kept of the quantities of waters released and subsequently stored within Don Pedro Reservoir. These quantities are "deposited" in CCSF's "bank account" within Don Pedro.

CCSF has absolutely no right to physically withdraw water from Don Pedro Reservoir. CCSF "withdraws" water from this bank account by diverting water upstream that otherwise would flow to the Districts under their senior water rights. CCSF may withhold these flows in quantities not to exceed CCSF's storage credit in Don Pedro Reservoir. The Districts, in turn, use the CCSF stored water in Don Pedro Reservoir to replace water that CCSF would otherwise be obligated to release to meet the Districts' senior water rights.

The Fourth Agreement thus allows CCSF to maximize its operational flexibility with respect to diversion and conveyance of water from the upper Tuolumne River. At the foundation, however, is the assumption that Hetch Hetchy is being operated as the major CCSF storage facility on the upper Tuolumne River. If Hetch Hetchy Reservoir no longer existed and CCSF wanted rights to divert water or physically store water in Don Pedro Reservoir, then CCSF would need to renegotiate the Fourth Agreement or negotiate a new agreement with the Districts. Likewise, because the Fourth Agreement was submitted to the FERC for approval as part of the hydroelectric licensing process for New Don Pedro, corresponding amendments may have to be made to the FERC license.

The water bank, utilizing releases from O'Shaughnessy Dam, also creates flexibility and reliability for the Districts and CCSF. Without Hetch Hetchy Reservoir, there would be a reduction of flexibility in the Hetch Hetchy system. According to a recent study, if an intertie were added to connect the lower Hetch Hetchy Aqueduct with New Don Pedro, additional conveyance capacity could be added to the system to bring the lower aqueduct to capacity and reduce the impact on water supply. Remaining storage in the upper Tuolumne River facilities would remain unchanged. [144]

V.
CEQA AND NEPA: THE ANALYSIS OF ALTERNATIVES

CCSF acknowledges that the existing conveyance facilities are not sufficient to contain increased flows from expanded exports of water from Hetch Hetchy. It will have to expand its pipeline system across the San Joaquin Valley if it is to deliver a greater quantity of water from the Hetch Hetchy system. Even a capital improvement program relative to existing facilities may result in increased availability of water to the Bay Area, with attendant

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[144] Null, *Re-Assembling Hetch Hetchy: Water Supply Implications of Removing O'Shaughnessy Dam* (2003) U.C. Davis MA Thesis at p. 29.

growth inducing and cumulative impacts. Such actions, being discretionary, will necessitate environmental documentation prepared in accordance with the requirements of CEQA[145], and NEPA[146].

The desire to expand, improve or otherwise update or modify CCSF's facilities for export of Tuolumne River water raises a number of other issues. Such activities might injure public trust and/or environmental resources. CCSF must consider alternatives to its existing upstream diversions, such as the diversion of water downstream within the system (the Delta). A diversion at a downstream location would avoid any upstream harm to public trust values and environmental resources while still allowing water to be put to reasonable beneficial use by CCSF. Proceeding in this manner would also maximize the reasonable beneficial use of water as required by Article X, Section 2 of the California Constitution by allowing water to flow through the entire Tuolumne and San Joaquin River systems to serve public trust and environmental purposes and still be diverted for CCSF's purposes.

This result would seem to be compelled by *National Audubon, supra*, dealing with Mono Lake, and the Lower American River trial court decision in *Environmental Defense Fund, Inc. v. East Bay Municipal Utility Dist.*, Alameda County Superior Court, No. 425,955. If the public trust and environmental values of Mono Lake and the Lower American River would justify this result, the benefit associated with Hetch Hetchy Valley, within a National Park, would seem to compel, at the very least, an analysis of this alternative.

VI.
RAKER ACT PUBLIC POWER REQUIREMENTS

A. Sale to San Francisco

The Raker Act explicitly requires CCSF to "develop and use hydroelectric power for the use of its people . . . ."[147] Further, the Raker Act prohibits CCSF from selling Hetch Hetchy electricity to a corporation or individual for resale.[148] The CCSF power supply requirements have been the source of significant political and legal conflict since their

145 Public Resources Code section 21000 et seq.
146 42 U.S.C. § 4231 et seq.
147 38 Stat. 248, § 9(m).
148 The Raker Act provides, in section 6, that CCSF is prevented "from ever selling or letting to any corporation or individual, except a municipality or a municipal water district or irrigation district, the right to sell or sublet the water or electric energy sold or given to it or him by the said grantee; *provided*, That the rights hereby granted shall not be sold, assigned, or transferred to any private person, corporation or association, and in case of any attempt to so sell, assign, transfer, or convey, this grant shall revert to the Government of the United States." (38 Stat. 245, § 6.)

inception.[149] This conflict generally focuses on the fact that CCSF has never developed its own infrastructure to directly deliver power to its residents.

Despite Congress' intent that CCSF would supply publicly generated power directly to the citizens of San Francisco and areas within the Districts, CCSF voters, over the years, rejected six separate bond measures that would have financed construction of the power infrastructure necessary for CCSF to directly supply electricity. After initially and unsuccessfully attempting to sell power to PG&E,[150] and after the six rejected infrastructure bond measures, CCSF now "wheels" power through PG&E facilities to CCSF's customers. Due to the Ninth Circuit's ruling in *Starbuck*, the wheeling agreement may only be challenged by a small number of parties, including the Secretary of Interior and, potentially, the Districts.[151]

The Raker Act gives the Secretary of the Interior the authority to require additional power production and supply by CCSF.[152] This decision is in the sole discretion of the Secretary of Interior.[153] CCSF's failure to comply with a request from the Secretary of the Interior to increase power production would empower the Secretary to revoke the right-of-way underlying the Hetch Hetchy system.[154]

B. Sale to Districts

The Raker Act also provides that CCSF must "sell or supply" electricity to the Districts or any municipality within the Districts on two conditions: (i) CCSF has electricity in excess of its demand for "actual municipal purposes"; and (ii) the electricity sold or supplied is used for "pumping subsurface water for drainage or irrigation" or for "actual municipal public purposes."[155] [156] Congress intended that the revenues generated from the sales of power would help to defray the costs of constructing the Hetch Hetchy project.

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149 See, e.g., *United States v. City and County of San Francisco, supra,* 310 U.S. at p. 28 [where the court found that CCSF's sale of electricity to PG&E violated the Raker Act]; *Starbuck v. City and County of San Francisco* (9th Cir. 1977) 556 F.2d 450 [where San Francisco residents unsuccessfully challenged CCSF's electricity "wheeling" agreement with PG&E].

150 In 1940 this arrangement was rejected by the court in *United States v. City and County of San Francisco, supra,* 310 U.S. at p. 28.

151 See *Starbuck, supra,* 556 F.2d at p. 457.

152 38 Stat. 249, § 9(n).

153 *Ibid.*; see also *United States v. City and County of San Francisco, supra,* 310 U.S. at pp. 29-30.

154 See *id.* at p. 30.

155 38 Stat. 248, § 9(l). TID, at least, asserts strongly that electricity in "excess" of San Francisco's needs is to be sold to TID, MID and municipalities within the two Districts, and that determining what is excess to the "actual municipal public purposes" of the "grantee" does *not* include electricity required for those purposes by CCSF's wholesale water supply customers.

156 The Raker Act states, in pertinent part:

> That the said grantee shall, upon request, sell or supply to said irrigation districts, and also to the municipalities within either or both said irrigation districts, for the use of any land owner

Footnote continued on following page.

C. Raker Act Requirements for Power Production

The Raker Act is fundamentally a public power act, as recognized in the FERC Examiner's Initial Decision on the New Don Pedro hydroelectric license, which characterized the Raker Act as the precursor of the Federal Power Act. The Raker Act's requirement for CCSF to develop power out of the Hetch Hetchy facilities that is purely public in character was a key justification for the congressional authorization of the right-of-way grant within Yosemite National Park. Although in the aftermath of the 1906 San Francisco earthquake CCSF itself was moved to pursue the Hetch Hetchy project to secure a more stable water supply, Congress, in 1914, saw the right-of-way grant as an opportunity for introducing cheap public power into the California market.[157] As a consequence, the act requires CCSF to produce power as a condition of the right-of-way grant.

The Raker Act imposes as a legal condition of the right-of-way a requirement that CCSF will develop hydroelectric power and make it available to the public, utilizing the Hetch Hetchy Project facilities. If CCSF elected to restore the Hetch Hetchy Valley, it would still be required to produce power from the Tuolumne River and sell it to municipal customers or the Districts to the extent its facilities still occupied other lands within the Park boundaries. Without releases from Hetch Hetchy Reservoir to be turned into the Kirkwood Powerhouse, CCSF would have to rely on the other reservoirs and powerhouses in its upper Tuolumne River development to meet the Raker Act's public power requirement, or else withdraw entirely from the Park, based on the reversion contained in section 6 of the Raker Act.

In sum, the public power conditions that Congress imposed in making its Yosemite Park right-of-way grant are significant constraints on CCSF's operation of the Hetch Hetchy project. Thus, even though the need for water was CCSF's initial purpose behind developing the Hetch Hetchy project, as part of the bargain that water supply now depends on its ability to continue to generate power for its citizens and municipal uses in San Francisco, as well as

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> or owners therein for pumping subsurface water for drainage or irrigation, or for the actual municipal public purposes of said municipalities (which purposes shall not include sale to private persons or corporations) any excess of electrical energy which may be generated, and which may be so beneficially used by said irrigation districts or municipalities, when any such excess of electric energy may not be required for pumping the water supply for said grantee and for the actual municipal public purposes of the said grantee (which purposes shall not include sale to private person or corporation) at such price as will actually reimburse the said grantee for developing and maintaining and transmitting the surplus electrical energy thus sold; . . .

38 Stat. 248, § 9(l).

[157] Picker, et al., *supra,* at pp. 1313-1314, citing H. Schussler, *The Water Supply of San Francisco, California, Before, During and After the Earthquake of April 18th* (1908) at p. 14.

in the Districts. CCSF must carefully balance any decision to remove its facilities from Hetch Hetchy Valley against this requirement.

VII.
CONCLUSIONS

A. Water

The rights and interests of CCSF and the Districts are intertwined, and probably impossible to separate. Together the Districts and CCSF have been through nearly a century of competition, of mutual reliance and agreements, of challenge and accommodation, of facing common threats, and of meeting new demands. The legal battles that have been endured have created a platform or foundation of expectations and promises that will continue to guide future responses to challenges that emerge. The long history of conflicts, culminating in agreements and compromises, provides a basis for continuing to work toward a common goal. If it is successfully asserted that Hetch Hetchy Valley should be restored, then CCSF and the Districts will be faced with the development of new means of meeting this challenge to CCSF's water rights and power producing capability. Alternatives may well exist, both physical and legal, and may be developed with enlightened guidance and historical perspective.

B. Power

The Raker Act requires CCSF to develop public hydroelectric power as a condition of the right-of-way Congress granted for the Hetch Hetchy project. Congress intended that the public should benefit from the right of way in this specific way. In the decades following the Raker Act, both the Districts and CCSF have enjoyed benefits from having power available from Hetch Hetchy.

But a great deal has changed in California's current electricity market and regulatory environment, much of which Congress could not have anticipated when it enacted the Raker Act or granted the license for New Don Pedro. Transmission wheeling and direct sales in a competitive commodities-style market were unheard of then, and their entry into the modern legal landscape may need to be considered. In any case, it is clear from the background of legislation, licensing and agreements regarding these matters that the public power conditions imposed on the right-of-way have been a guiding principle for CCSF. Future development of Hetch Hetchy hydroelectric facilities, or removal of them from Hetch Hetchy Valley, must be undertaken consistent with that historical commitment.

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